NAVAL POSTGRADUATE SCHOOL
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THESIS

INTEGRATION OF AN APPLE II PLUS COMPUTER
INTO AN
EXISTING DUAL AXIS SUN TRACKER SYSTEM

by

Roger J. Morais

June 1984

Thesis Advisor: H. Titus

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This thesis describes the integration of an Apple II plus computer into an existing sun tracking system. The Apple Computer replaced an Intel 80/10A single board computer as the system controller. Software development and hardwiring were necessary to successfully integrate the new computer into the system. With the new computer installed, user interaction with the tracking system became possible. Additionally it was

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#20 - ABSTRACT - (CONTINUED)

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Integration of an Apple II plus Computer into an Existing Dual Axis Sun Tracker System

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ABSTRACT

This thesis describes the integration of an Apple II plus computer into an existing sun tracking system. The Apple Computer replaced an Intel 80/10A single board computer as the system controller. Software development and hardwiring were necessary to successfully integrate the new computer into the system. With the new computer installed, user interaction with the tracking system became possible. Additionally it was possible to replace hard to interpret assembly language code with higher level Basic code as the system controlling software.

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I. INTRODUCTION

As the finite conventional energy sources of the world are depleted, and their costs increase, alternative energy sources are becoming more and more attractive. Although in many instances these alternative sources cannot compete economically with gas, oil, and other conventional sources, it is just a matter of time until alternative and conventional sources will be competitive. Already many homes have solar collectors and other devices designed to decrease the consumption of gas, oil, and electricity. Prototype solar power plants are appearing in various parts of the world, and geothermally produced power is now a viable option in areas where this natural resource is available. In short, our energy sources are shifting, and by necessity will continue to shift, from the non-renewable to the renewable.

Of the renewable energy sources available, solar energy is by far the most abundant. On the average, $1.7 \times 10E14$ kilowatts of solar power continually reach the Earth. If all of this power could be captured and used, it would amount to approximately 5000 times the rate at which power is currently consumed by the entire Earth's population [Ref. 1]. It should be clear that the development of techniques for the conversion of this resource into usable forms of energy is essential to our future as an industrial nation.

One method that is available for converting solar energy into a usable form involves the use of solar thermal collectors. This type of collector captures the sun's radiated energy and transfers the resultant thermal energy to a fluid, which in turn transfers its thermal energy to the user, or places it in a storage facility [Ref. 1].

Solar collectors can be divided into broad categories: the nonconcentrating flat plate collectors, and the concentrating collectors. Flat plate collectors are for the most part stationary, and do not concentrate the energy received by them. In the northern hemisphere flat plate collectors are normally set facing south, and are tilted back to an angle equal to the local latitude plus 10 degrees as shown in Figure 1. In this position the flat plate collector is able to efficiently convert radiated energy into thermal energy for a large range of incidence angles. Point concentrating collectors on the other hand require an incidence angle close to zero to effectively focus the captured radiated energy onto a small area, or a receiver vessel. This means that, in order to maintain a usable incidence angle, either the reflector or its associated receiver must move in response to the sun's changing celestial position. The greater the concentration factor of the particular collector, the more critical the incidence angle of the sun's rays becomes.

The decision to use one collector type over another depends to a large extent upon its intended use. For low

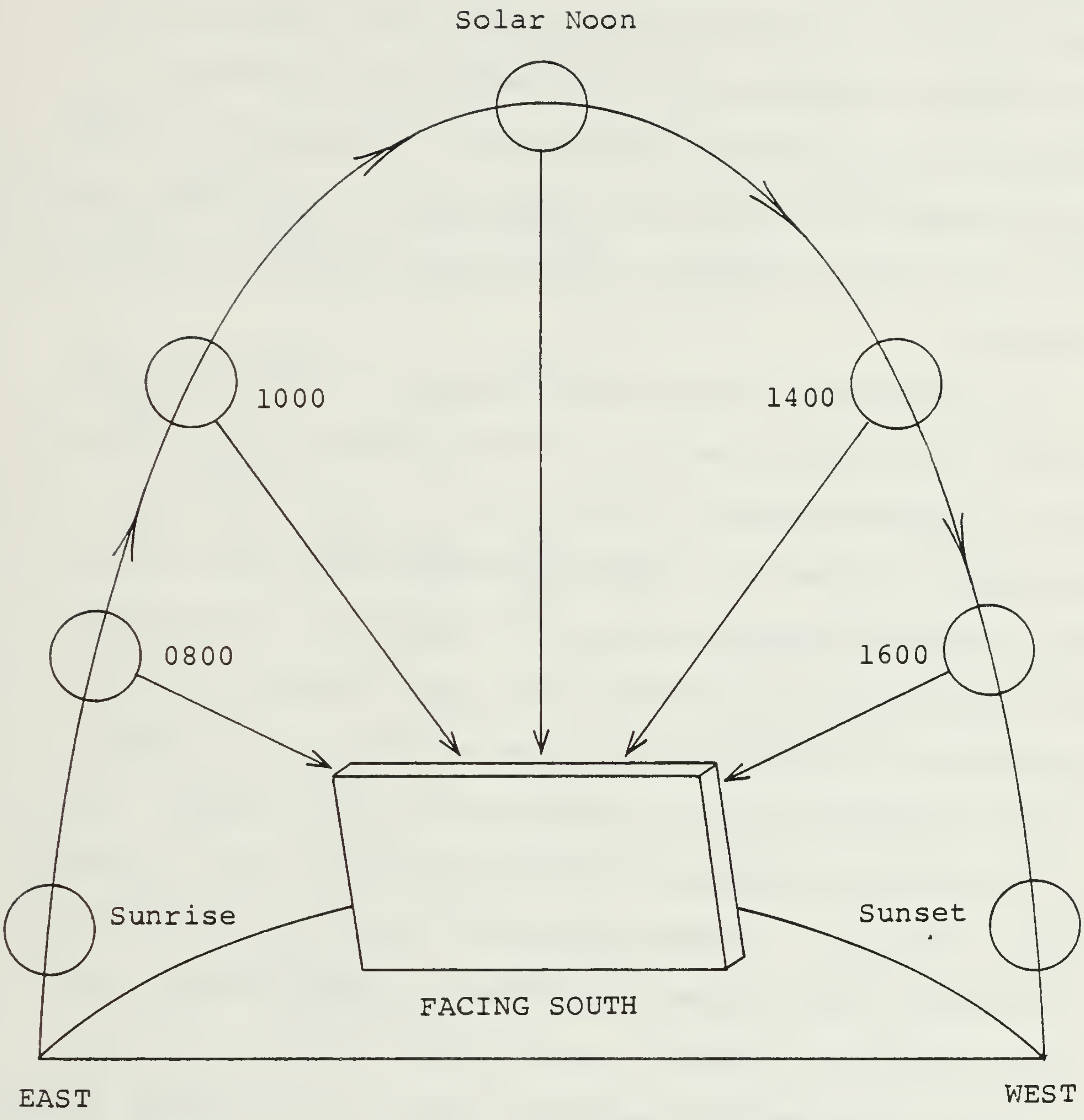
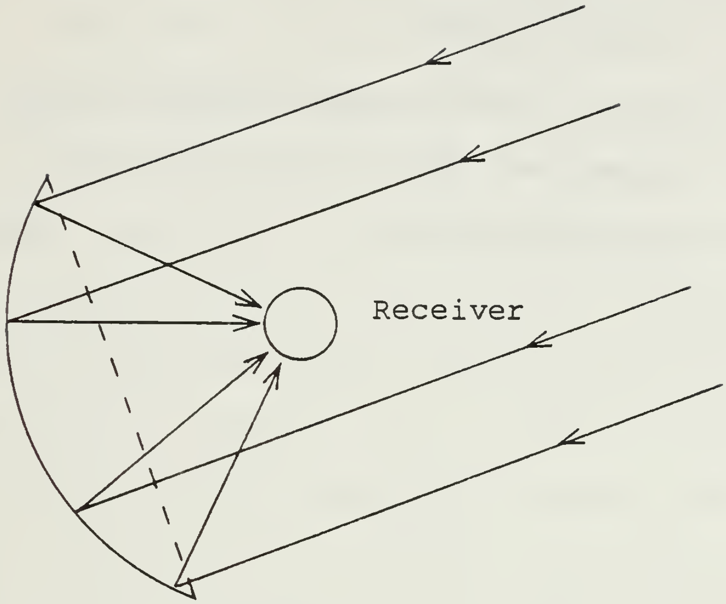


Figure 1. A Flat Plate Collector and the Sun's Track for a Typical One Day Period

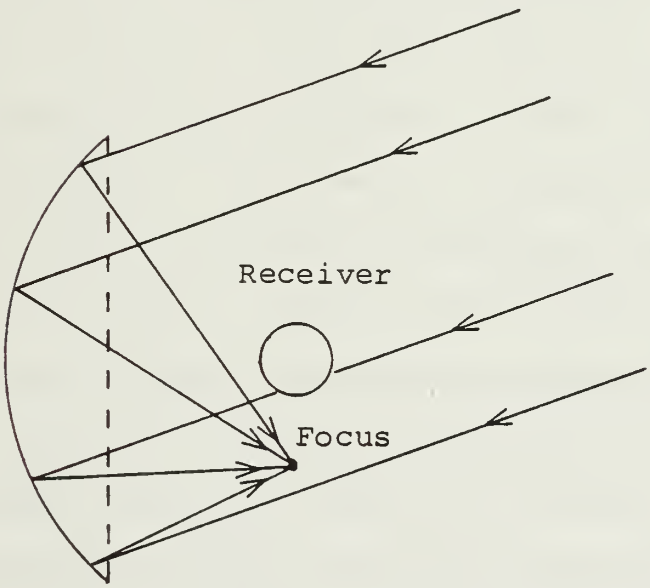
temperature applications the fixed plate collector would normally be the correct choice, but for higher temperature applications the concentrating collector should be used. Power plant applications, for example, use concentrating collectors to produce the high temperatures necessary to generate turbogenerator drive steam. Household hot water and swimming pool heating systems, on the other hand, would use flat plate collectors for both economical and practical reasons.

As mentioned, a point concentrating collector's efficiency is a direct function of how accurately the collector can be pointed directly at the sun. A point focusing type collector is usually a mirror surfaced parabolic reflector. This reflector captures the solar radiation that strikes it, and reflects the energy to a point called the focus. A receiver is placed at the focus and is heated to very high temperatures by the concentrated solar energy. Liquid in the receiver absorbs the heat and can be used to perform work, Figure 2A. If the reflector is not pointed directly at the sun, the incidence angle is not zero and the focus shifts from the receiver, as in Figure 2B.

The mechanism that keeps the point concentrating collector pointed at the sun is the main topic of this research. An Apple II plus micro computer is used to control a Dual Axis Sun Tracking system. The system used already existed, but was controlled by an Intel 80/10A Single Board Computer [Ref. 2].



(a) Incidence Angle 0°



(b) Incidence Angle 20°

Figure 2. A Point Concentrating Collector

Additionally the controlling software was written in assembly language, and downloaded onto EPROM'S. The 80/10A was replaced by an Apple II plus computer to (1) allow for user interaction with the sun tracking system and (2) to have the controlling software written in the easier to understand Basic programming language.

II. SYSTEM DESIGN

A. SYSTEM COMPONENT DESCRIPTION

The solar tracking system consists of three main components. The first is a mechanism known as a Dual Axis Solar Tracking Device. This device consists of two stepping motors for horizontal and vertical drive power, four photo diode sensors used for sun location and tracking, and four limit switches that ensure the tracker drive axis are limited in the amount they can rotate, thus preventing system wrap around, and providing start position information. Figures 3 and 4 show front and side views of the solar tracking component. Figure 3 shows the location of the two stepping drive motors, and the layout of the photo diode sensors (ES,WS,US,DS). As shown the horizontal and vertical stepping motors drive the sensor platform and sensor arm through a series of gears. The horizontal motor causes the platform to rotate through a maximum 180 degree arc in either direction, while the vertical motor causes the sensor arm to move through a maximum 90 degree arc between the up and down positions. Figure 4 shows the sensor arm, the limit switches (EL,WL,UL,DL), and the signals into and out of the tracker. The signals consist of four electrical current values that are proportional to the intensity of the light falling on each sensor, four ON (+5V) or OFF (-5V) signals from the

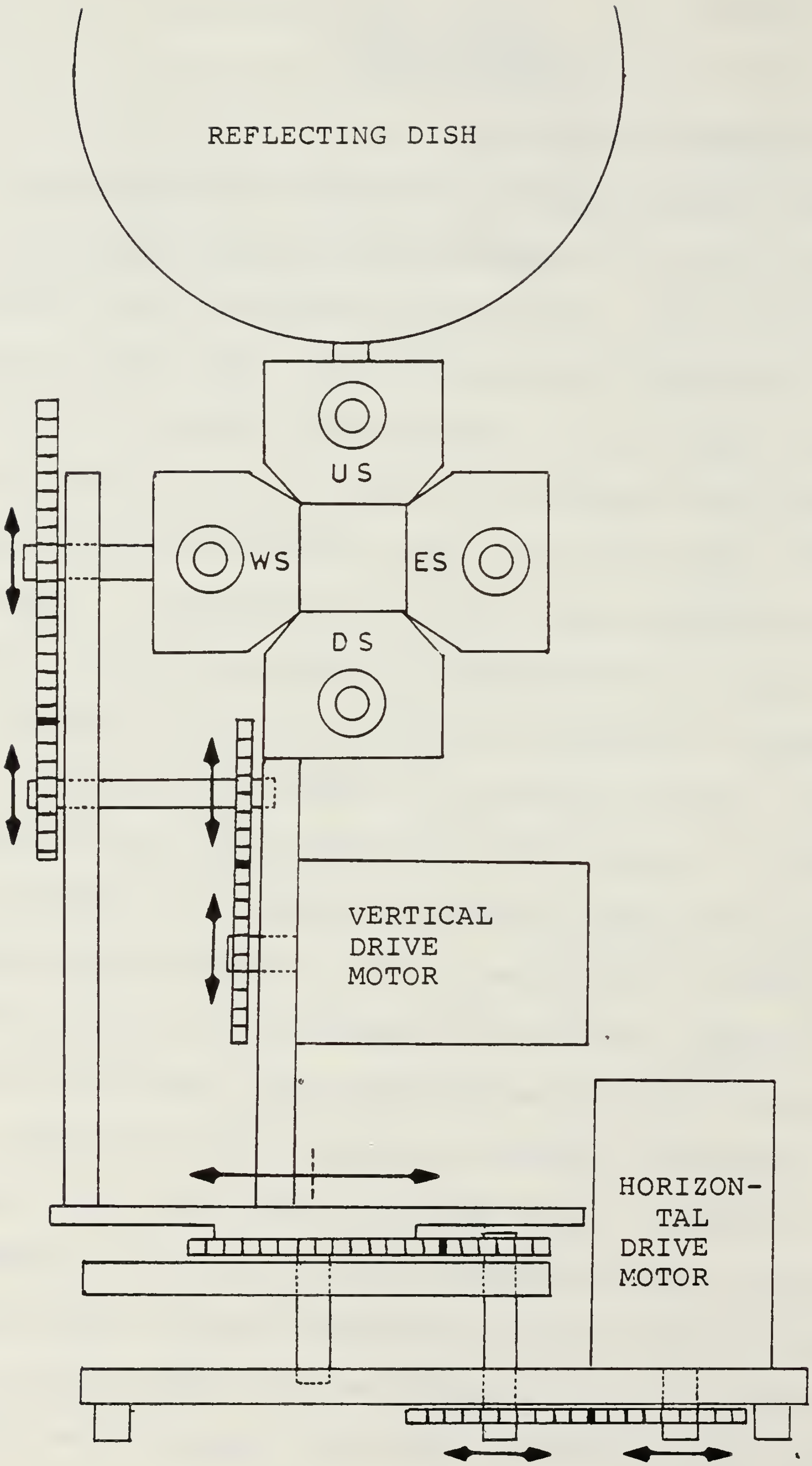


Figure 3. Dual Axis Sun Tracker (Front View)

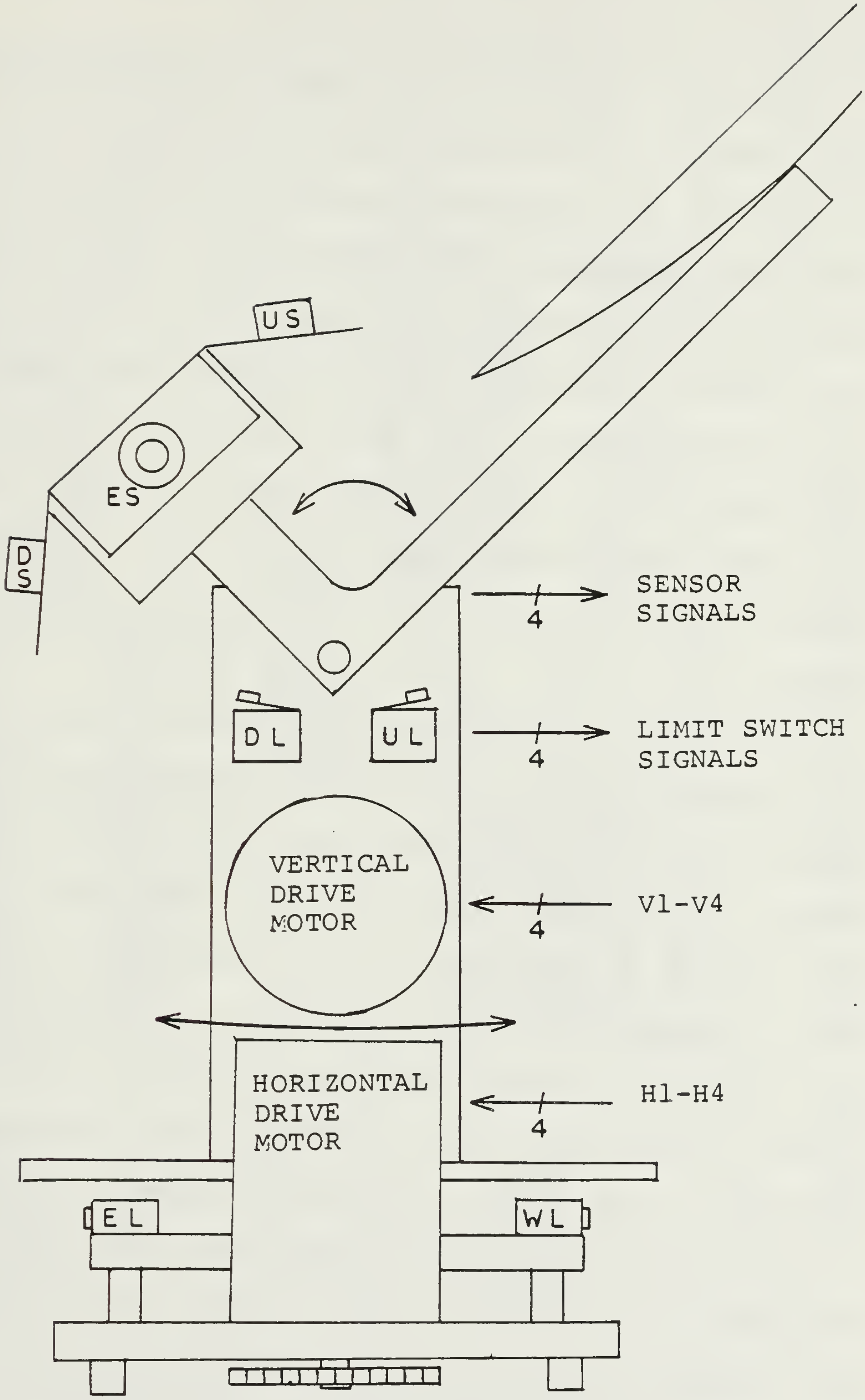


Figure 4. Dual Axis Sun Tracker (Side View)

limit switches, and drive signals from the controlling computer to the stepping drive motors.

The next component of the system is called the Amplification/Isolation box, hereafter called the A/I box. This box contains the circuitry necessary to interface the controlling computer to the sun tracker. Motor drive commands arriving from the computer are amplified and sent on to the drive motors, and sensor signals are amplified before being sent to the computer. Also associated with the amplification circuitry are isolation circuits to protect the computer from short circuits and power surges. The limit switch signals also go through the A/I box on their way to the computer, but are not altered in the process.

The third main component is the Apple II plus computer. This component with its associated software takes in the sensor data and provides the proper drive motor control signals to locate and track the sun. Limit switch values are also checked to determine if the tracker has reached the limit of a particular drive direction. As mentioned the Apple replaced the Intel computer so that the system would be user interactive, and the software would be easier to interpret in the higher level Basic language. Figure 5 is a system block diagram which shows the signal flow between components, as well as the internal flow of the computer. The analog to digital card and controlling software within the computer will be discussed in detail later.

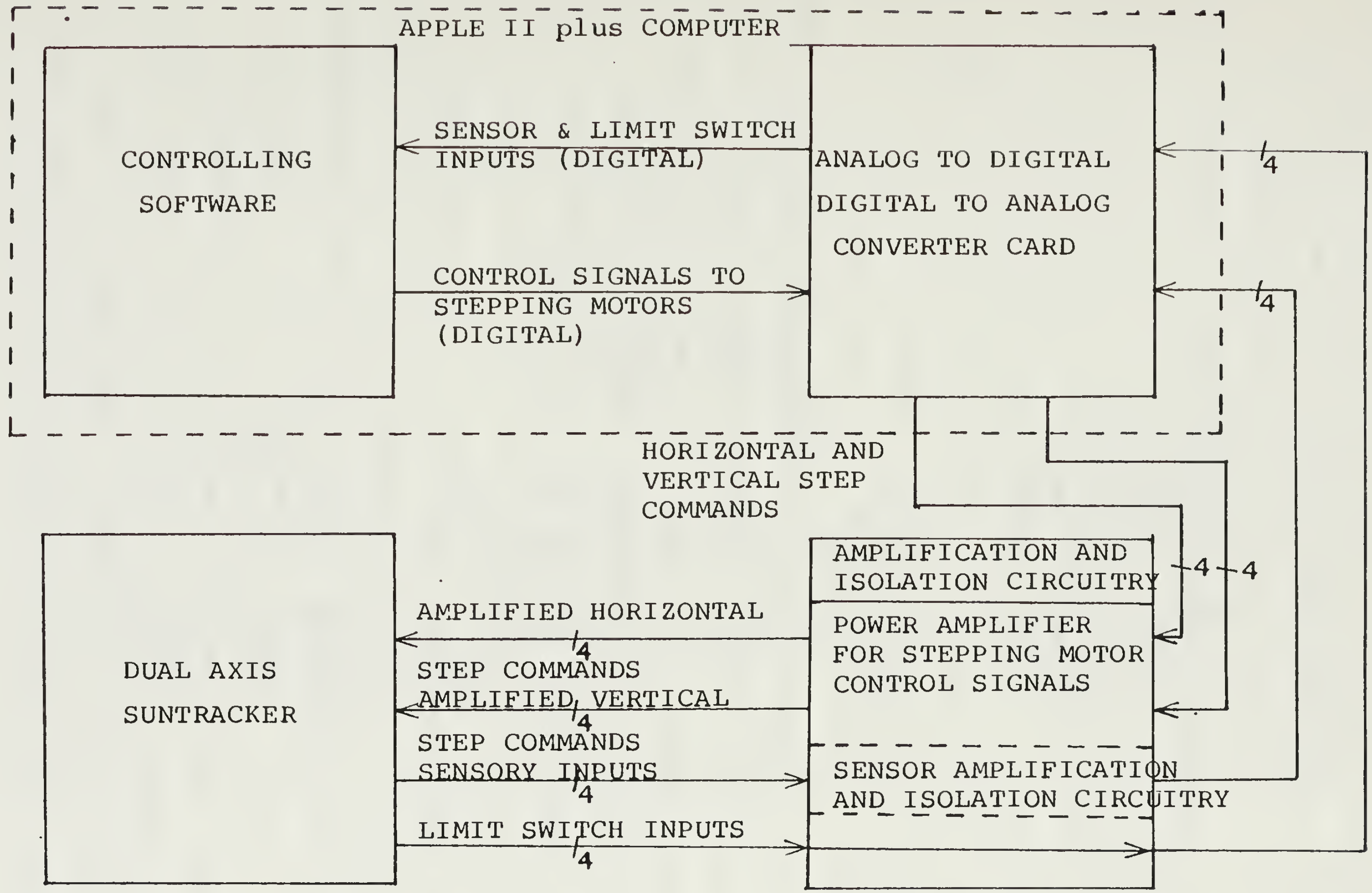


Figure 5. Solar Tracker System Block Diagram

B. SYSTEM STRUCTURE

While some system operation and hardware descriptions were available in [Ref. 2], they were insufficient to provide the detailed system knowledge necessary to integrate a new computer into the system. It was therefore necessary to begin the integration process by performing a thorough system trace out.

The A/I box was the initial and main focus of this trace out since all system signals enter and exit this component. First, all wires entering and leaving the box were traced. Figure 6 and Table 1 describe the results of this effort. Jacks one through three and single wire connections A through V are illustrated with their associated inputs and outputs, these inputs and outputs are further described in Table 1. It should be noted that the microprocessor referenced in the signal descriptions is the original Intel 80/10A and not the Apple. These signals are provided since the Intel hook up was left intact so it can still be used if desired. The Apple is connected inside the A/I box via a bus bar. Once the input and output connections were determined, the A/I boxes internal electronics could be traced. Figure 7 and Table 2 show the layout of the circuit board inside the A/I box, and describe the signals entering and leaving it. Note that the four LM747 OPAMP chips are all connected up identically, but only the east sensor (ES) hook up is drawn to avoid cluttering the

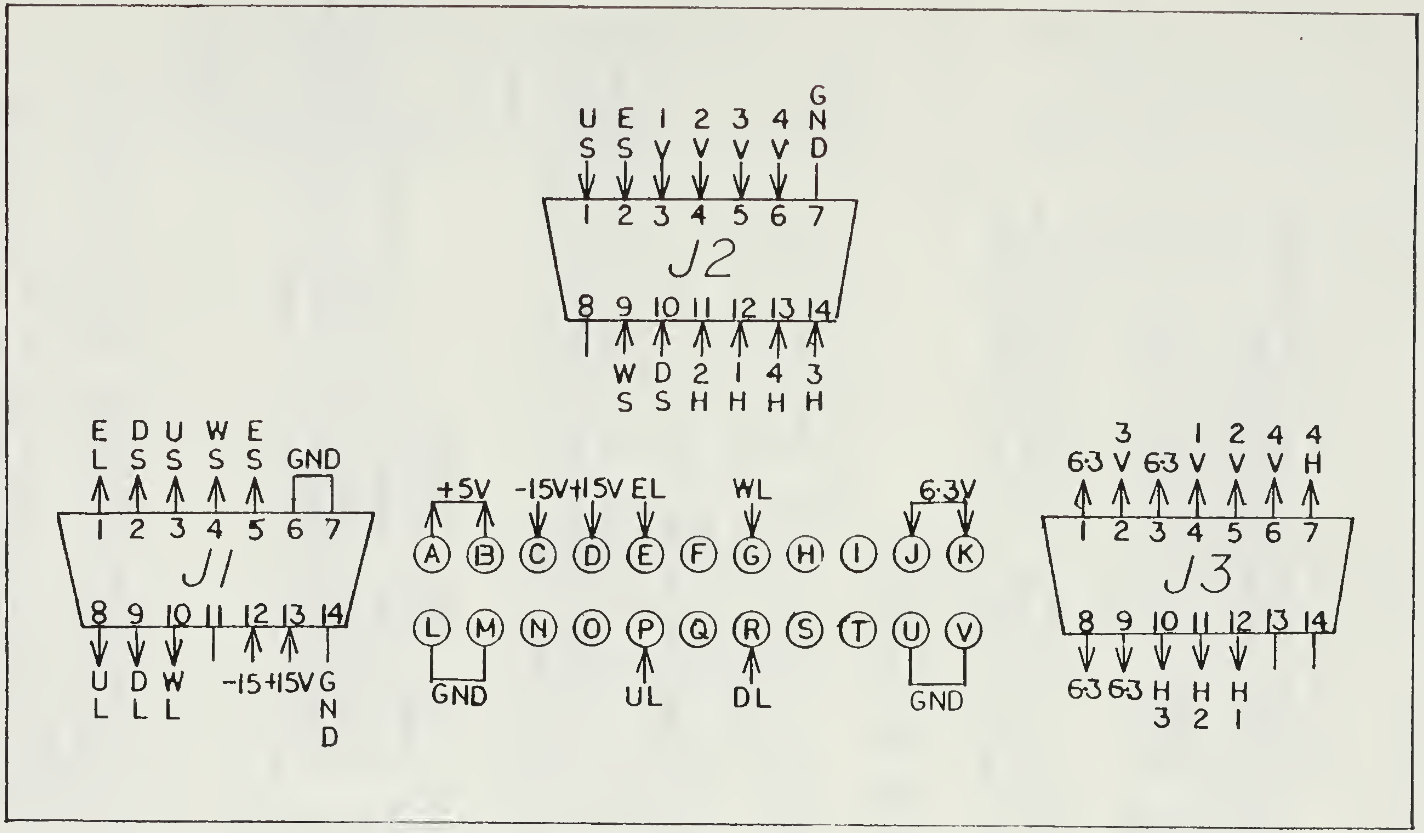


Figure 6. Plug Wiring Diagram for Top of Amplification/Isolation Box

TABLE 1

SIGNAL DESCRIPTION FOR TOP OF AMPLIFICATION/ISOLATION BOX

JACK J1

(1) EAST LIMIT SWITCH SIGNAL TO MICROPROCESSOR
(2) DOWN SENSOR SIGNAL TO MICROPROCESSOR
(3) UP SENSOR SIGNAL TO MICROPROCESSOR
(4) WEST SENSOR SIGNAL TO MICROPROCESSOR
(5) EAST SENSOR SIGNAL TO MICROPROCESSOR
(6) GROUND
(7) GROUND
(8) UP LIMIT SWITCH SIGNAL TO MICROPROCESSOR
(9) DOWN LIMIT SWITCH SIGNAL TO MICROPROCESSOR
(10) WEST LIMIT SWITCH SIGNAL TO MICROPROCESSOR
(11) NOT USED
(12) +15 VOLTS TO LM 747 CHIP
(13) -15 VOLTS TO LM 747 CHIP
(14) GROUND

JACK J2

(1) UP SENSOR INPUT FROM TRACKER
(2) EAST SENSOR INPUT FROM TRACKER
(3) VERTICAL DRIVE STEP ELEMENT #1 FROM MICROPROCESSOR
(4) VERTICAL DRIVE STEP ELEMENT #2 FROM MICROPROCESSOR
(5) VERTICAL DRIVE STEP ELEMENT #3 FROM MICROPROCESSOR
(6) VERTICAL DRIVE STEP ELEMENT #4 FROM MICROPROCESSOR
(7) GROUND
(8) NOT USED
(9) WEST SENSOR INPUT FROM TRACKER
(10) DOWN SENSOR INPUT FROM TRACKER
(11) HORIZONTAL DRIVE STEP ELEMENT #1 FROM MICROPROCESSOR
(12) HORIZONTAL DRIVE STEP ELEMENT #2 FROM MICROPROCESSOR
(13) HORIZONTAL DRIVE STEP ELEMENT #3 FROM MICROPROCESSOR
(14) HORIZONTAL DRIVE STEP ELEMENT #4 FROM MICROPROCESSOR

JACK J3

(1) +6.3 VOLTS TO VERTICAL STEPPING MOTOR
(2) AMPLIFIED VERTICAL STEP ELEMENT #3 TO VERTICAL STEPPING MOTOR
(3) +6.3 VOLTS TO VERTICAL STEPPING MOTOR
(4) AMPLIFIED VERTICAL STEP ELEMENT #1 TO VERTICAL STEPPING MOTOR

(5) AMPLIFIED VERTICAL STEP ELEMENT #2 TO VERTICAL STEPPING MOTOR
(6) AMPLIFIED VERTICAL STEP ELEMENT #4 TO VERTICAL STEPPING MOTOR
(7) AMPLIFIED HORIZONTAL STEP ELEMENT #4 TO HORIZONTAL STEPPING MOTOR
(8) +6.3 VOLTS TO HORIZONTAL STEPPING MOTOR
(9) +6.3 VOLTS TO HORIZONTAL STEPPING MOTOR
(10) AMPLIFIED HORIZONTAL STEP ELEMENT #3 TO HORIZONTAL STEPPING MOTOR
(11) AMPLIFIED HORIZONTAL STEP ELEMENT #2 TO HORIZONTAL STEPPING MOTOR
(12) AMPLIFIED HORIZONTAL STEP ELEMENT #1 TO HORIZONTAL STEPPING MOTOR
(13) NOT USED
(14) NOT USED

SINGLE PIN JACKS

(A) +5 VOLTS
(B) +5 VOLTS TO LIMIT SWITCHES
(C) -15 VOLT INPUT WHEN NOT USING INTEL 80/10A
(D) +15 VOLT INPUT WHEN NOT USING INTEL 80/10A
(E) EAST LIMIT SWITCH SIGNAL FROM TRACKER
(F) NOT USED
(G) WEST LIMIT SWITCH SIGNAL FROM TRACKER
(H) NOT USED
(I) NOT USED
(J) +6.3 VOLTS FROM EXTERNAL POWER SUPPLY
(K) +6.3 VOLTS FROM EXTERNAL POWER SUPPLY
(L) GROUND
(M) GROUND
(N) NOT USED
(O) NOT USED
(P) UP LIMIT SWITCH SIGNAL FROM TRACKER
(Q) NOT USED
(R) DOWN LIMIT SWITCH SIGNAL FROM TRACKER
(S) NOT USED
(T) NOT USED
(U) GROUND
(V) GROUND

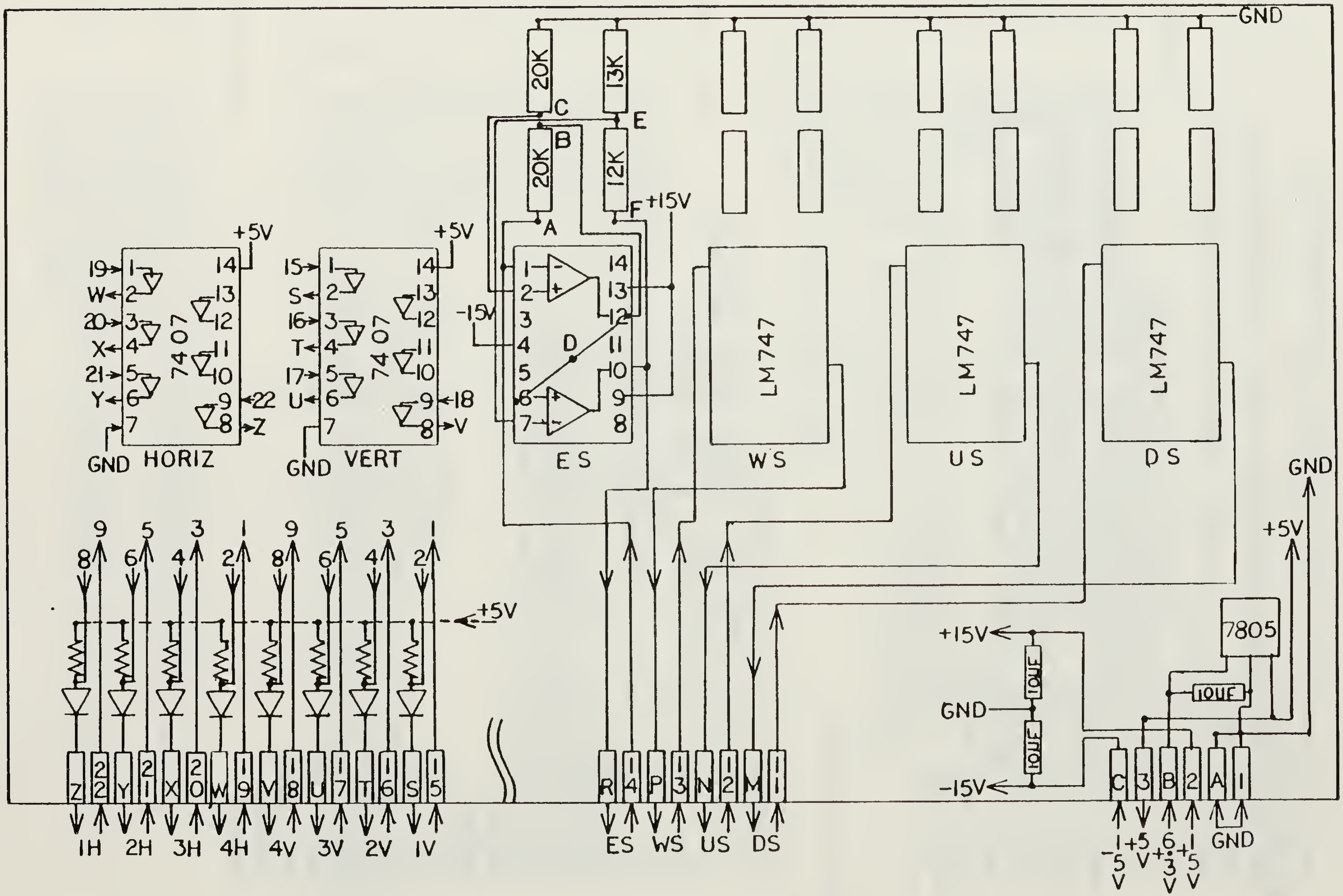


Figure 7. Schematic Diagram of Circuit Board Inside Amplification/Isolation Box

TABLE 2

AMPLIFICATION/ISOLATION BOX CIRCUIT BOARD SIGNALS
(LETTERED PINS ARE ON TOP OF CIRCUIT BOARD)

(A) GROUND
(1) GROUND
(B) +6.3 VOLTS TO 7805 VOLTAGE REGULATOR FOR +5 VOLTS REGULATED SUPPLY TO 7407 CHIPS
(2) +15 VOLTS IN FOR LM 747 CHIPS
(C) -15 VOLTS IN FOR LM 747 CHIPS
(3) +5 VOLTS OUT USED BY LIMIT SWITCHES
(M) DOWN SENSOR AMPLIFIED SIGNAL OUTPUT
(11) DOWN SENSOR UNAMPLIFIED SIGNAL INPUT TO LM 747 CHIP
(N) UP SENSOR AMPLIFIED SIGNAL OUTPUT
(12) UP SENSOR UNAMPLIFIED SIGNAL INPUT TO LM 747 CHIP
(P) WEST SENSOR AMPLIFIED SIGNAL OUTPUT
(13) WEST SENSOR UNAMPLIFIED SIGNAL INPUT TO LM 747 CHIP
(R) EAST SENSOR AMPLIFIED SIGNAL OUTPUT
(14) EAST SENSOR UNAMPLIFIED SIGNAL INPUT TO LM 747 CHIP
(S) VERTICAL STEP ELEMENT #1 OUTPUT TO POWER TRANSISTOR BASE
(15) VERTICAL STEP ELEMENT #1 INPUT FROM MICROPROCESSOR
(T) VERTICAL STEP ELEMENT #2 OUTPUT TO POWER TRANSISTOR BASE
(16) VERTICAL STEP ELEMENT #2 INPUT FROM MICROPROCESSOR
(U) VERTICAL STEP ELEMENT #3 OUTPUT TO POWER TRANSISTOR BASE
(17) VERTICAL STEP ELEMENT #3 INPUT FROM MICROPROCESSOR
(V) VERTICAL STEP ELEMENT #4 OUTPUT TO POWER TRANSISTOR BASE
(18) VERTICAL STEP ELEMENT #4 INPUT FROM MICROPROCESSOR
(W) HORIZONTAL STEP ELEMENT #4 OUTPUT TO POWER TRANSISTOR BASE
(19) HORIZONTAL STEP ELEMENT #4 INPUT FROM MICROPROCESSOR
(X) HORIZONTAL STEP ELEMENT #3 OUTPUT TO POWER TRANSISTOR BASE
(20) HORIZONTAL STEP ELEMENT #3 INPUT FROM MICROPROCESSOR
(Y) HORIZONTAL STEP ELEMENT #2 OUTPUT TO POWER TRANSISTOR BASE
(21) HORIZONTAL STEP ELEMENT #2 INPUT FROM MICROPROCESSOR
(Z) HORIZONTAL STEP ELEMENT #1 OUTPUT TO POWER TRANSISTOR BASE
(22) HORIZONTAL STEP ELEMENT #1 INPUT FROM MICROPROCESSOR

figure. Additionally all signals entering and leaving the circuit board apply to either the Intel or Apple computers. Figure 8 shows the remainder of the electronics inside the A/I box, namely the eight power transistors used to amplify the step signals sent to the stepping motors. The step elements V1 through V4 and H1 through H4 will be explained in detail later. Figure 9 and Table 3 are included only for completeness of system documentation, and to avoid future duplication of effort. They represent the Intel 80/10A wiring and signal description.

C. SYSTEM OPERATION

Once the signal flow had been determined, the actual system operation was the next focus of investigation. This information was necessary because the characteristics of the signals coming into, and the type of the signals going out of the new computer had to be known.

There were two areas of investigation during the system operation phase. The first was the two driver stepping motors, and their control circuitry. A thorough understanding of their operation was essential to the later development of the software drive routines. As no technical documentation was readily available for the stepping motors that were used, the following data was obtained from [Ref. 2], experimentation, name plate data, and general stepping motor theory [Ref. 3]. The motors used were Superior Electric synchronous

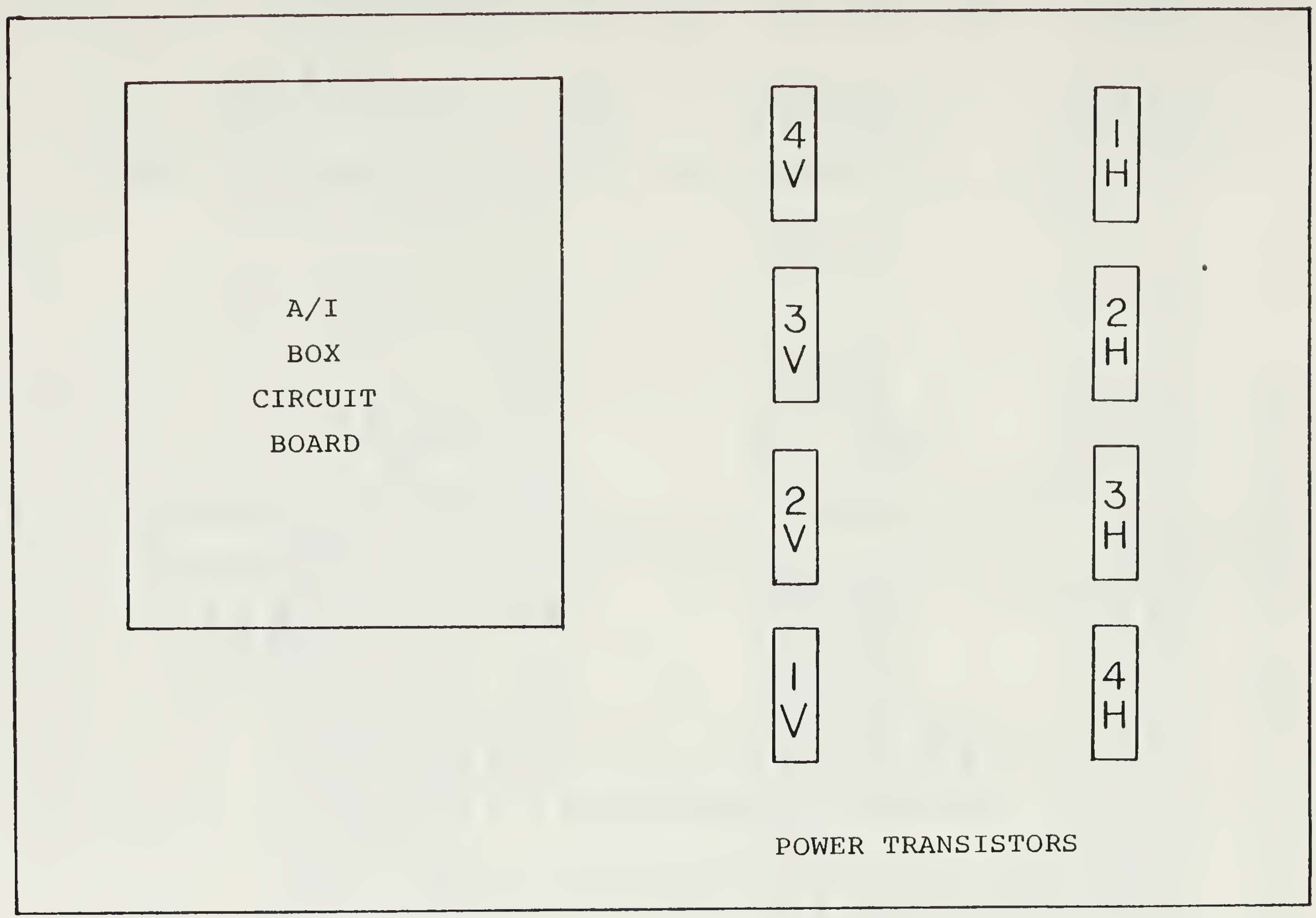


Figure 8. Power Transistor Layout Inside Amplification/Isolation Box

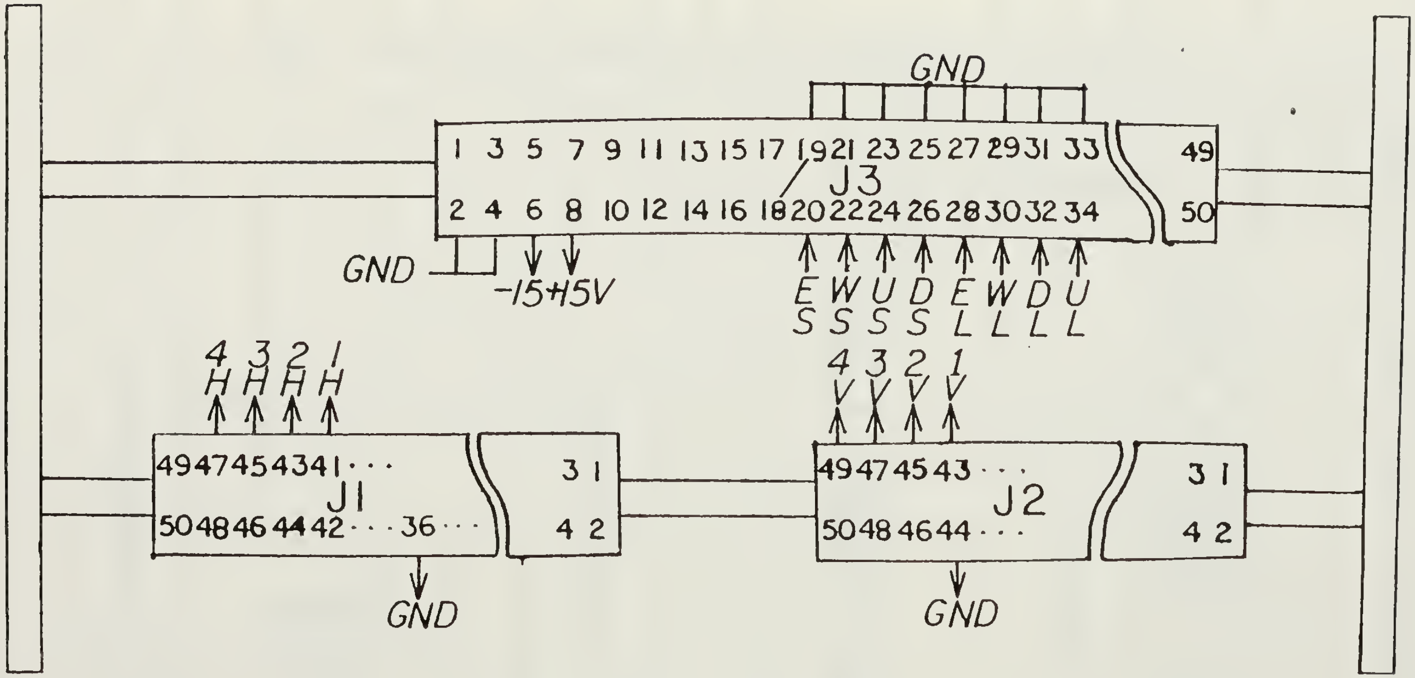


Figure 9. INTEL 80/10A Single Board Computer Connections

TABLE 3

INTEL 80/10A SINGLE BOARD COMPUTER CONNECTIONS

JACK J1

(36) GROUND
(41) HORIZONTAL STEP ELEMENT #1 TO AMPLIFIER/ISOLATION BOX
(43) HORIZONTAL STEP ELEMENT #2 TO AMPLIFIER/ISOLATION BOX
(45) HORIZONTAL STEP ELEMENT #3 TO AMPLIFIER/ISOLATION BOX
(47) HORIZONTAL STEP ELEMENT #4 TO AMPLIFIER/ISOLATION BOX
(REMAINING PINS NOT USED)

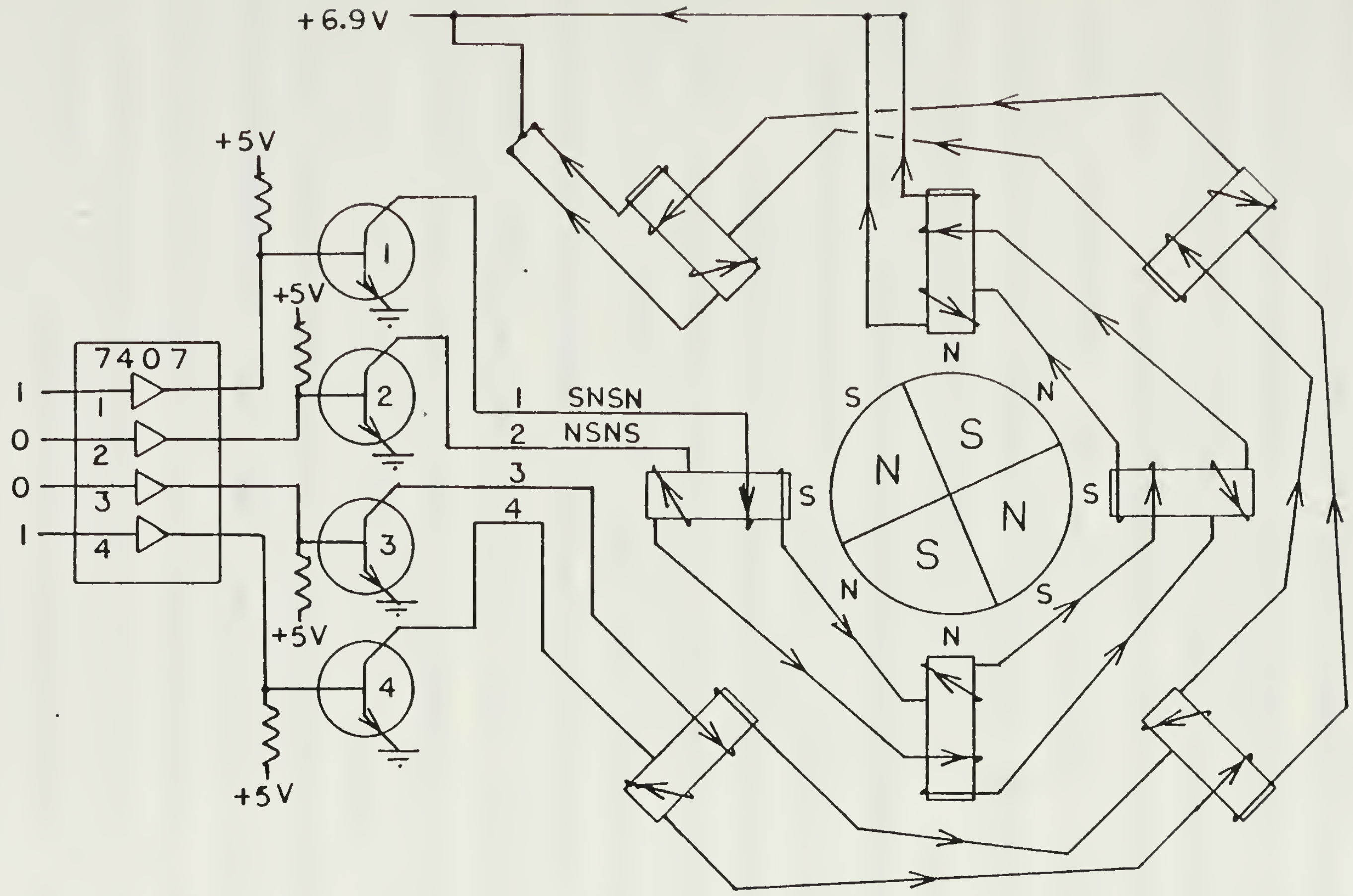
JACK J2

(44) GROUND
(43) VERTICAL STEP ELEMENT #1 TO AMPLIFIER/ISOLATION BOX
(45) VERTICAL STEP ELEMENT #2 TO AMPLIFIER/ISOLATION BOX
(47) VERTICAL STEP ELEMENT #3 TO AMPLIFIER/ISOLATION BOX
(49) VERTICAL STEP ELEMENT #4 TO AMPLIFIER/ISOLATION BOX
(REMAINING PINS NOT USED)

JACK J3

(2) GROUND
(4) GROUND
(6) -15 VOLTS TO AMPLIFIER/ISOLATION BOX
(8) +15 VOLTS TO AMPLIFIER/ISOLATION BOX
(18,19,21,23,25,27,29,31,33) GROUND
(20) EAST SENSOR INPUT FROM AMPLIFIER/ISOLATION BOX
(22) WEST SENSOR INPUT FROM AMPLIFIER/ISOLATION BOX
(24) UP SENSOR INPUT FROM AMPLIFIER/ISOLATION BOX
(26) DOWN SENSOR INPUT FROM AMPLIFIER/ISOLATION BOX
(28) EAST LIMIT SWITCH INPUT FROM AMPLIFIER/ISOLATION BOX
(30) WEST LIMIT SWITCH INPUT FROM AMPLIFIER/ISOLATION BOX
(32) DOWN LIMIT SWITCH INPUT FROM AMPLIFIER/ISOLATION BOX
(REMAINING PINS NOT USED)

stepping motors that have a nominal DC voltage rating of 6.9 Volts and a rated amperes per winding value of 1.6 Amps. Figure 10 is a schematic representation of a typical stepping motor, and its interface to the system. In this schematic the rotor is a four pole permanent magnet (large circle). There are eight stators, each of which is an electromagnet. These stators are divided into two groups of four. One group is controlled by power transistors 1 and 2, the other by 3 and 4. Each stator is wound by wire in two directions. For the set controlled by power transistors 1 and 2 the polarities of each stator depend on whether transistor 1 or 2 is turned on. The left hand rule for electron current flow can be used to determine the polarity of each sensor. By wrapping the fingers of the left hand around the stator in the direction of current flow, the north pole is determined to be the end of the stator that the thumb points to. For example if transistor 1 is turned on, electron current will flow from the grounded terminal of the transistor to the +6.9 Volts at the top of the diagram. By applying the left hand rule, a S-N-S-N configuration is observed. If transistor 2 were conducting a N-S-N-S configuration would result. Transistors 1 and 2 conducting at the same time is not a valid state. Transistors 3 and 4 control the other set of stators in a similar manner. It is by this ability to alter the polarity of these stator sets that the stepping motion of the motors is realized. An example step command is illustrated in the



(arrows indicate the direction of electron current flow)

Figure 10. Schematic Diagram of Typical Stepping Motor

figure. In this instance a 1001 step is input to a 7407 noninverting hex driver chip. A "1" represents a +5 Volt high signal, and a "0" represents a zero Volt low signal. When a low signal is applied, the driver can sink up to 30mA., and the +5 Volts at the base of the transistor is dropped across the base resistor thus keeping the transistor turned off. When a high signal is sensed the driver becomes an open circuit, and the +5 Volts is no longer dropped across the base resistor. The +5 Volts is sensed at the base of the NPN transistor, and it is turned on. Current can now be conducted through the stator windings so that the stators are polarized. With the above description in mind, the 1001 step example can easily be shown to produce the indicated stator polarizations. Finally remembering that unlike poles attract, the rotor orientation is set as shown.

In summary each step command to the stepping motor has four step elements, as in the 1001 example. The first two elements control one set of four stators, and the last two steps the second set. The polarity configuration of a stator set is determined by which of the two controlling step elements is high.

The above description is for a four pole rotor with eight stators. The actual stepping motor used has four 50 pole rotors stacked one above the other, each offset slightly from the one below it. This offset in essence gives a 100 pole rotor. There are still only eight electromagnetic

stators, but each has five high points on its surface. The magnetic field is concentrated at the high points giving the appearance of five stators of the same polarity. This large number of poles allows the step size to be either 0.9 or 1.8 degrees, depending upon the drive sequence used to step the motor. These step sizes correspond to either 400 or 200 steps per 360 degree revolution. The example that was discussed in Figure 10 would have produced 22.5 or 45 degree steps for 16 or 8 steps per revolution, again depending upon the drive sequence used. The smaller steps of the real motor are clearly more useful in real world applications than the large steps of the example.

As mentioned the step size depends on the drive sequence used. Figure 11 shows a four step loop. Notice that each change in stator polarization produces a 45 degree movement of the rotor. The loop is repeated over and over to drive the stepping motor the desired number of steps. In this case the loop must be repeated twice per 360 degree revolution. It should be noted that step one produced a 45 degree movement of the rotor to place it in the first position, so that four steps produce a 180 degree transition. The small numbers 1 and 2 on the first step, mark the starting positions of the first and second stator sets. The stators are laid out in the same manner as those in Figure 10. Again the first two elements of each step control stator set one, and the last two stator set two. Figure 12 is a typical eight step loop.

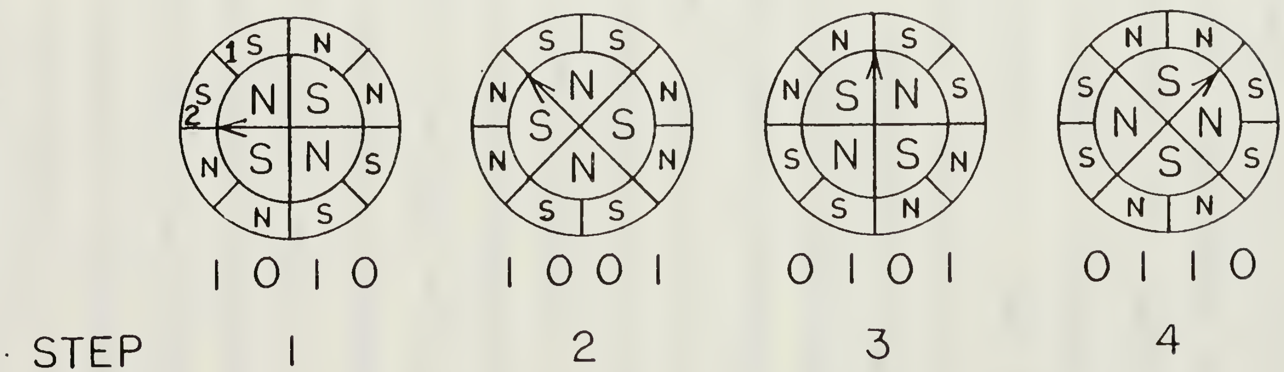


Figure 11. Four Step Drive Routine

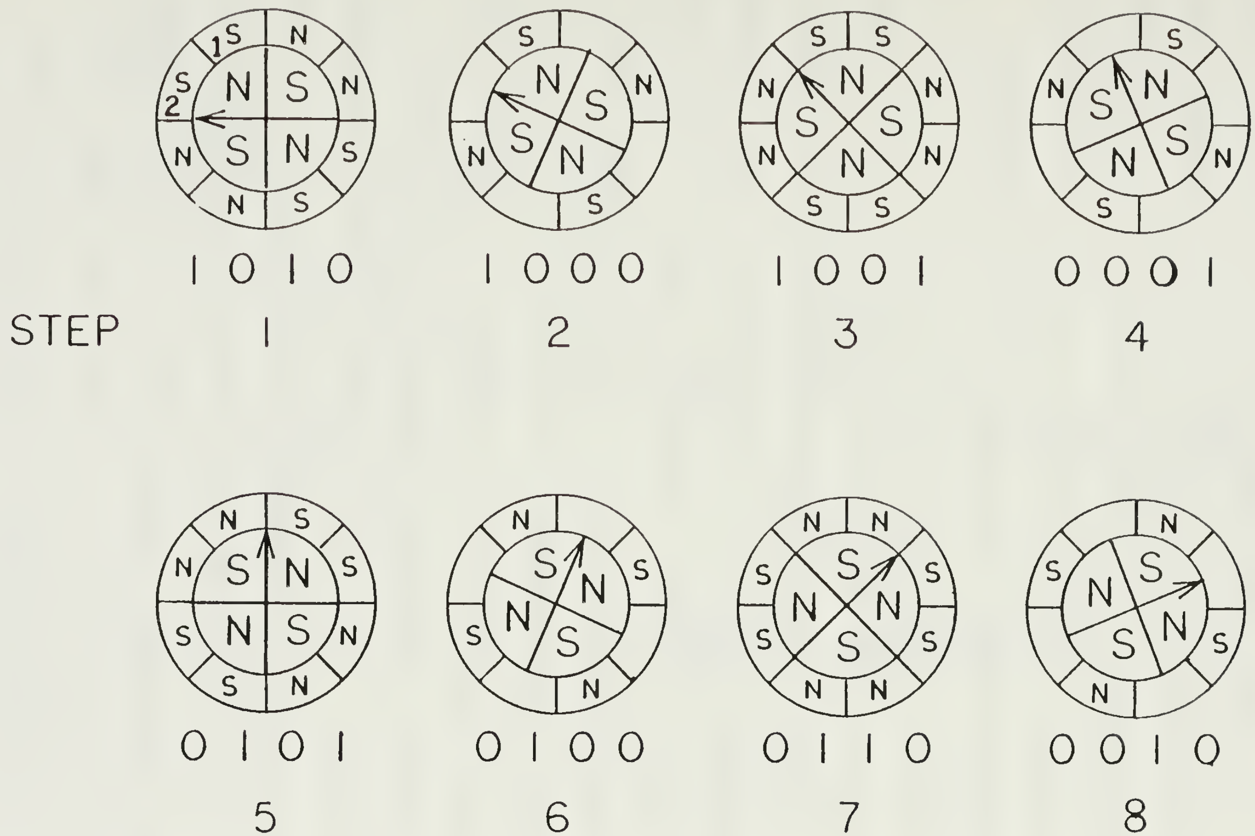


Figure 12. Eight Step Drive Sequence

In this case each step moves the rotor 22.5 degrees. The smaller steps are realized by inserting four extra steps between the original four. In each of the extra steps one of the stator sets is left off by not turning on either of its associated transistors. The rotor aligns itself as illustrated, on the energized stator set. It is these same 4 and 8 step loops that produce the 0.9 and 1.8 degree steps of the real drive motors. The only difference is that the loop must be repeated many more times per motor revolution. With the above information, drive routines for the new computer could now be developed.

The second of the two main areas of investigation was the sensor circuitry. As mentioned the sensors are photodiodes that generate a current proportional to the intensity of the light falling on them. Figure 13 shows sensor output signal amplification circuitry for the east sensor. The letters A through F correspond to the letters at the top of the A/I box circuit board shown in Figure 7, so that this figure can be tied to the actual hardware. The circuit operates as follows. The first op amp provides a voltage output proportional to the current input from the energized photodiode. This voltage is then further amplified by the second op amp, to provide a signal that is usable by the computer. This output varies from near zero volts when the sensor is in a shadow, to near 2.5 volts in the bright sunlight.

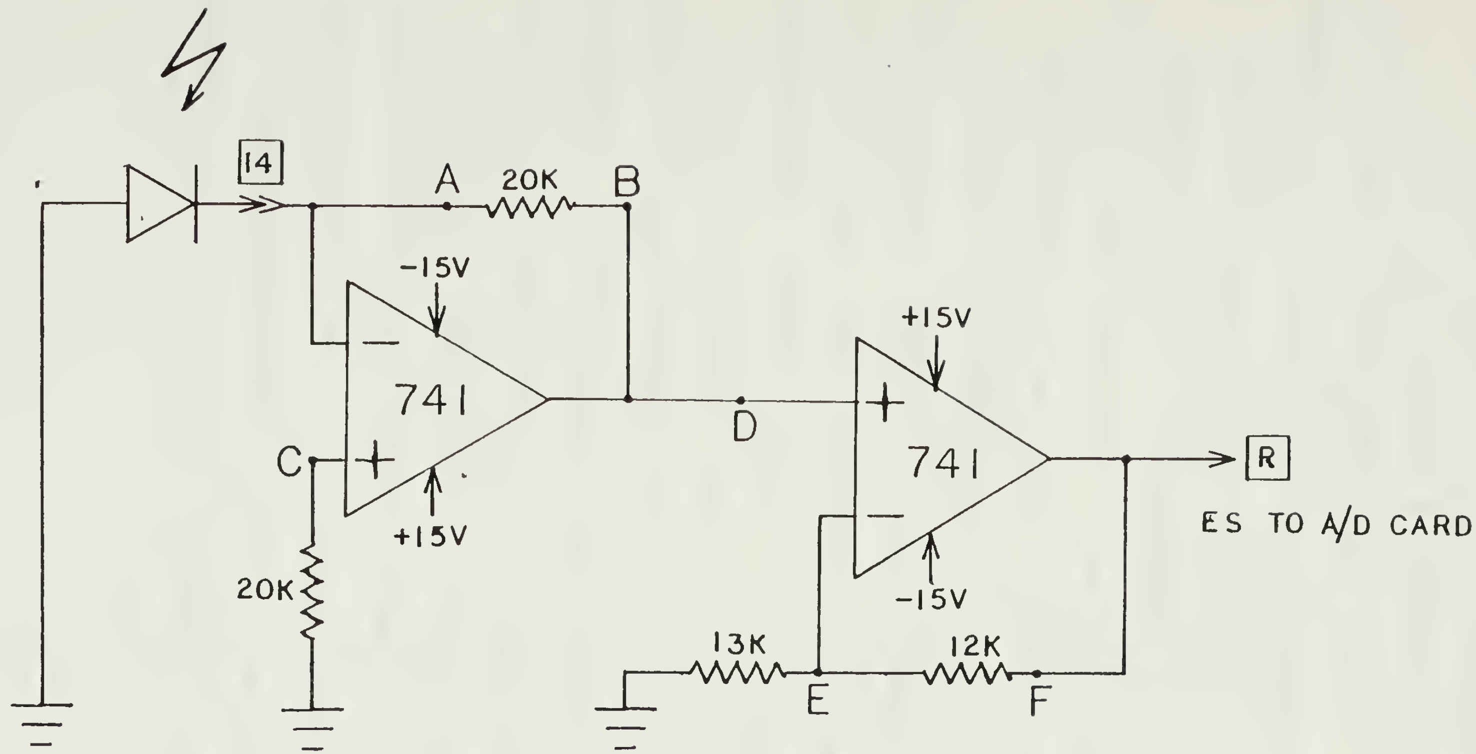


Figure 13. Sensor Signal Amplification Circuit

D. COMPUTER INTEGRATION

With the preliminary research complete, the problem of integrating the new computer into the system could be taken up. The Apple II Plus computer is equipped with several internal card slots, so that integrated circuit cards which perform many different functions can be added to the computer. After some difficulty in choosing a card to use for interfacing the computer to the system, an analog to digital/digital to analog card (A/D card) was chosen [Ref. 4]. This card has 16 channels of analog input and 16 channels of analog output. Each of the 32 channels has an address and can be accessed by software commands. Eight of the digital to analog output channels (4 per motor) were used to deliver the drive step commands to the stepper motors. Additionally eight of the analog to digital input channels were used to input the 4 sensor and the 4 limit switch signals. Figure 14 shows the A/D card and the jacks coming from it. These jacks are connected to two similar jacks coming from the A/I box. Table 4 describes the signals on the jacks, lists the A/D card channel associated with each pin (whether used or not), and gives the color of the wire associated with each signal for ease of identification. With the hardware interfacing completed the development of the controlling software could begin.

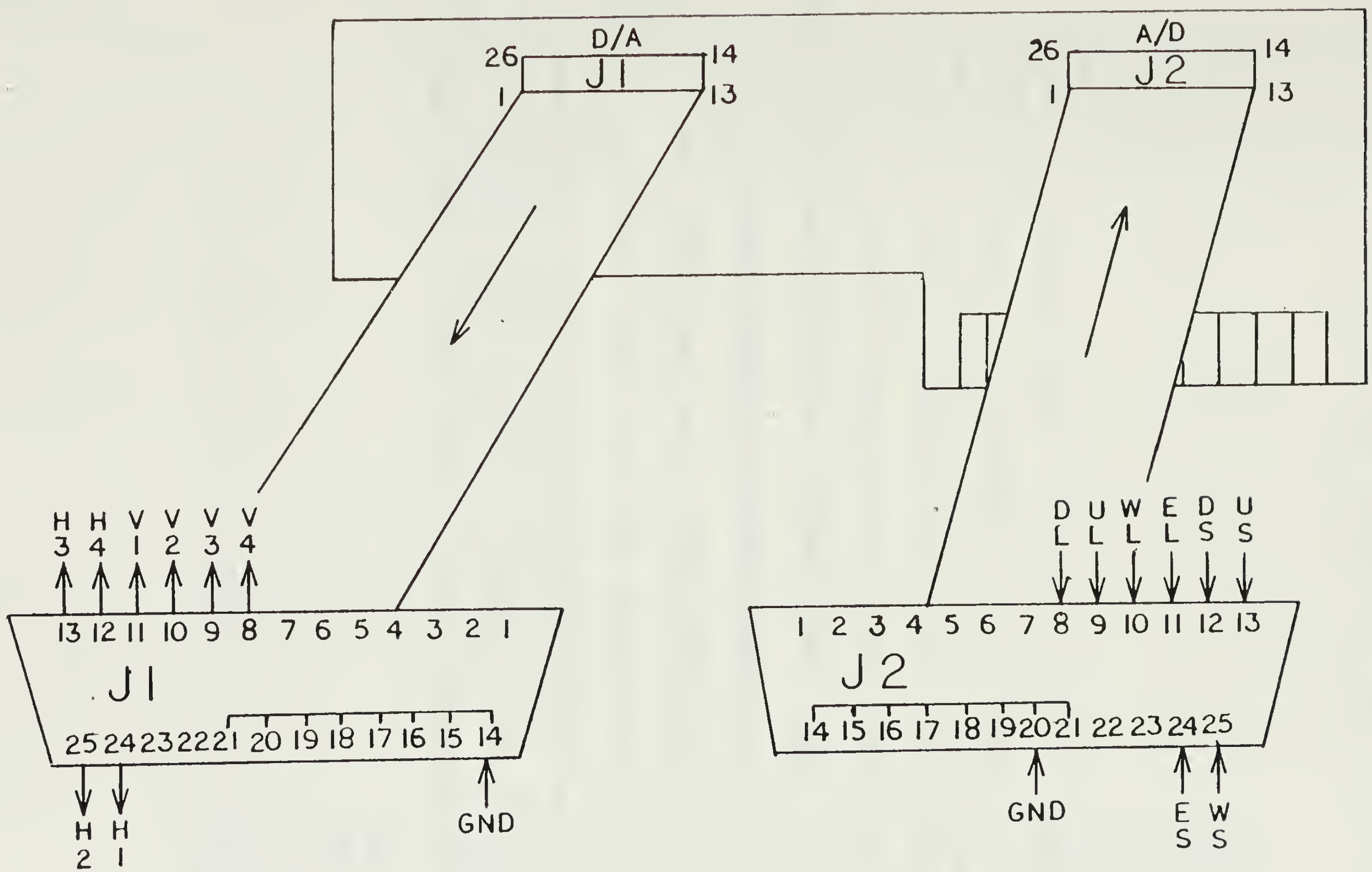


Figure 14. Analog to Digital Card with Connecting Jacks

TABLE 4

LISTING OF THE A/D CARD JACK CONNECTIONS
(WIRE COLOR GIVEN AT END OF SIGNAL DESCRIPTION)
(NOTE CARD CHANNEL GIVEN BELOW SIGNAL DESCRIPTION)

JACK #1

(1) NOT USED
CHANNEL 15
(2) NOT USED
CHANNEL 14
(3) NOT USED
CHANNEL 13
(4) NOT USED
CHANNEL 12
(5) NOT USED
CHANNEL 11
(6) NOT USED
CHANNEL 10
(7) NOT USED
CHANNEL 9
(8) VERTICAL STEP ELEMENT #4 TO AMP/ISOLATION BOX (YELLOW)
CHANNEL 8
(9) VERTICAL STEP ELEMENT #3 TO A/I BOX (GREEN)
CHANNEL 7
(10) VERTICAL STEP ELEMENT #2 TO A/I BOX (RED)
CHANNEL 6
(11) VERTICAL STEP ELEMENT #1 TO A/I BOX (BLUE)
CHANNEL 5
(12) HORIZONTAL STEP ELEMENT #4 TO A/I BOX (YELLOW)
CHANNEL 4
(13) HORIZONTAL STEP ELEMENT #3 TO A/I BOX (GREEN)
CHANNEL 3
(14-21) COMMON GROUNDS, GROUND WIRE FROM A/I BOX IN 14
(BLACK)
(22) NOT USED
(23) NOT USED
CHANNEL 0
(24) HORIZONTAL STEP ELEMENT #1 TO A/I BOX (BLUE)
CHANNEL 1
(25) HORIZONTAL STEP ELEMENT #2 TO A/I BOX (RED)
CHANNEL 2

JACK #2

(1) NOT USED
CHANNEL 15
(2) NOT USED
CHANNEL 14
(3) NOT USED
CHANNEL 13
(4) NOT USED
CHANNEL 12
(5) NOT USED
CHANNEL 11
(6) NOT USED
CHANNEL 10
(7) NOT USED
CHANNEL 9
(8) DOWN LIMIT SWITCH INPUT FROM A/I BOX (YELLOW)
CHANNEL 8
(9) UP LIMIT SWITCH INPUT FROM A/I BOX (GREEN)
CHANNEL 7
(10) WEST LIMIT SWITCH INPUT FROM A/I BOX (RED)
CHANNEL 6
(11) EAST LIMIT SWITCH INPUT FROM A/I BOX (BLUE)
CHANNEL 5
(12) DOWN SENSOR INPUT FROM A/I BOX (YELLOW)
CHANNEL 4
(13) UP SENSOR INPUT FROM A/I BOX (GREEN)
CHANNEL 3
(14-21) COMMON GROUNDS, GROUND WIRE FROM A/I BOX IN 20 (BLACK)
(22) NOT USED
(23) NOT USED
CHANNEL 0
(24) EAST SENSOR INPUT FROM A/I BOX (BLUE)
CHANNEL 1
(25) WEST SENSOR INPUT FROM A/I BOX (RED)
CHANNEL 2

III. SOFTWARE DESIGN

A. INITIAL PLANNING

The controlling software for the system was developed in three distinct phases. The first phase was the design of the driver routines for the system stepping motors. The second phase was the development of the sensor and limit switch inputs. The third phase was to combine the first two phases into a program that would control the system in the desired manner. The program developed in the last phase had to be capable of obtaining the input data from the 4 photo-diode sensors, analyzing it, and causing the appropriate drive motor to turn in the proper direction. The program must also ensure that none of the limit switches had been depressed, and react accordingly if one had been.

B. DRIVE ROUTINE DESIGN

As was mentioned previously, the Apple computer has several internal slots available for the installation of various cards. Since each drive step consists of 4 bits of information, a parallel I/O card was initially chosen to output the step information to the drive motors. Specifically an A488 Communication Interface card was chosen [Ref. 5]. This card is designed for communication between the Apple and digitally controlled peripherals. The card has 8 bi-directional data lines, and 8 control lines. The data sent

and received by the card is by means of the ASCII character set. The control lines of the card are used for interdevice synchronization and data transmission setup commands. Attempts were made to utilize this card by having it output the ASCII character whose last four bits corresponded to the desired drive step. Figure 15 is an example of a program developed for an 8 step drive routine. Lines 70 through 170 are setup commands required by the card, and 180 through 370 are the dirve loop. All attempts to make this card work failed due to the lack of handshaking and control signals coming from the seeker system.

The A/D card mentioned in the last section was also in the computer, and was to be used for the conversion of the analog input signals into a digital form usable by the computer. The fact that the A/D card also had 16 output channels lead to the idea that these channels could be used to produce the necessary drive steps. It was concluded that if the 4 elements comprising the step arrived at the stepping motor in rapid serial succession rather than at the same instant in parallel form, the stepping motor would still perform satisfactorily. This would allow for the use of only one card for the complete system interface, rather than the two required if the A488 were used.

The value of a particular A/D card output channel is set by sending a number from 0 to 255 to the channel address. The following are some of the output voltage values corresponding to various numbers sent to the channel.

```
*** PROGRAM TO DRIVE SEEKER WITH     ***
***    A488 PARALLEL I/O CARD        ***


10   SL% = 5
20   DT$ = "SUN:01"
30   RS$ = ""
40   FS$ = ""
50   CI$ = ""
60   PA% = 1
70   X = 256 * SL%
80   IC = 49152 + X
90   SN = IC + 16
100  FI = IC + 32
110  PA = IC + 96
120  SO = IC + 192
130  SR = 49295 + SL% * 16
140  PE = 1144 + SL%:DU = 1272 + SL%
150  EOS = 1912 + SL%
160  CALL FI:
170  CALL IC:
180  FOR T = 1 TO 16:RS$ = RS$ + "": NEXT
190  FOR A = 1 TO 100
200  CI$ = "S,SUN":FS$ = "J": CALL SN:
210  PA% = 100: CALL PA:
220  CI$ = "S,SUN":FS$ = "H": CALL SN:
230  PA% = 100: CALL PA:
240  CI$ = "S,SUN":FS$ = "I": CALL SN:
250  PA% = 100: CALL PA:
260  CI$ = "S,SUN":FS$ = "A": CALL SN:
270  PA% = 100: CALL PA:
280  CI$ = "S,SUN":FS$ = "E": CALL SN:
290  PA% = 100: CALL PA:
300  CI$ = "S,SUN":FS$ = "D": CALL SN:
310  PA% = 100: CALL PA:
320  CI$ = "S,SUN":FS$ = "L": CALL SN:
330  PA% = 100: CALL PA *
340  CI$ = "S,SUN":FS$ = "B": CALL SN:
360  PA% = 100: CALL PA:
370  NEXT A
380  END
```

Figure 15. A488 Drive Routine

NUMBER	OUTPUT
0	-5.0 Volts
64	-2.5
128	0.0
192	+2.5
255	+5.0

From the table is can be seen that the card can output from -5 to +5 volts in .039 Volt increments. The values 128 and 255 were chosen to represent the 0 and the 1 values for each step element. Analog output channels 1-4 were used for the 4 horizontal drive step elements, and 5-8 for the vertical step elements (see Table 4). To define a particular output from a channel, the base channel address must first be computed. To do this the equation M = 49,280 + (slot number*16) is used. Here the 49,280 is the starting address of all slot dependent locations in the computer, and the slot number is an integer from 1 to 7, depending upon the slot that the card was installed in. Next a channel number from 0 to 15 must be added to the base address M in order to address a particular channel on the card. Note that the A/D card must be installed in slot number four if the sun seeker program is to work properly. Once the A/D card channel address (M+ CHANNEL ADDRESS) has been calculated, the POKE command can be used to input any value to the channel within the allowable range. POKE is a BASIC command which has the form POKE(memory address),(desired value). Figure

16 is an early drive routine using the POKE command. The slot number that the card is installed in is given in line 10, lines 20-45 assign step element values to an array, and lines 50-120 are three nested Do Loops. The inner most Do Loop I, calculates the memory base value M, and POKES the values of the indicated array element into the proper card channel (M+I). So the basic memory value M is incremented by adding the Do Loop values I (1-4) to it, thus four channel addresses are calculated. These addresses correspond to the A/D card channels used to output the 4 element drive step. These addresses together with the desired output voltage values are placed in POKE commands to form the step. The next Do Loop in Figure 16 (the H loop), generates a four step loop like that of Figure 11. Finally the G loop causes the 4 step drive loop to be repeated 60 times.

When this routine was run it suddenly became clear that great programming efficiency would be necessary if any kind of acceptable system response times were to be achieved. To make a transition of only 90 degrees with this drive routine, 25 seconds were required. In other words to move the tracker from an east to a west facing position, it would take close to one minute. Figure 17 is the same drive routine as that of Figure 16, except that the M calculation was taken out of the Do Loop,and calculated only once at the beginning of the program. This simple change reduced the 90 degree transition time to 12 seconds, for a savings of 13 seconds. While this

```
***  FIRST DRIVE ROUTINE USING A/D  ***
*** CARD. MEMORY CALCULATION IN LOOP***
***   REQUIRED 25 SEC. FOR 90 DEG   ***
***          TRANSITION.            ***


10    SL = 4
20    DIM D(16)
30    D(1) = 255:
      D(2) = 128:
      D(3) = 255:
      D(4) = 128
35    D(5) = 255:
      D(6) = 128:
      D(7) = 128:
      D(8) = 255
40    D(9) = 128:
      D(10) = 255:
      D(11) = 128:
      D(12) = 255
45    D(13) = 128:
      D(14) = 255:
      D(15) = 255:
      D(16) = 128
50    FOR G = 1 TO 60
60    FOR H = 1 TO 4
70    FOR I = 1 TO 4
75    M = 49280 + (SL * 16)
80    POKE M + I,D(I + (4 * (H - 1)))
90    NEXT
110   NEXT
120   NEXT
```

Figure 16. 25 Second Drive Routine

```
***     SECOND DRIVE ROUTINE.          ***
***     BY MOVING MEMORY CALC.         ***
***  OUTSIDE LOOP, REDUCED TRANSIT     ***
***  TIME TO 12.4 SEC FOR A 90 DEG     ***
***          TRANSITION.               ***


10    SL = 4
15    M = 49280 + (SL * 16)
20    DIM D(16)
30    D(1) = 255:
      D(2) = 128:
      D(3) = 255:
      D(4) = 128
35    D(5) = 255:
      D(6) = 128:
      D(7) = 128:
      D(8) = 255
40    D(9) = 128:
      D(10) = 255:
      D(11) = 128:
      D(12) = 255
45    D(13) = 128:
      D(14) = 255:
      D(15) = 255:
      D(16) = 128
50    FOR G = 1 TO 60
60    FOR H = 1 TO 4
70    FOR I = 1 TO 4
80    POKE M + I,D(I + (4 * (H - 1)))
90    NEXT
110   NEXT
120   NEXT
```

Figure 17. 12 Second Drive Routine

change cut the time in half, still more time would have to be cut because in actual use the drive routine would have logic placed between the steps, further slowing it down.

Figure 18 shows the third drive routine developed. To increase execution speed the step elements were taken out of an array, and placed directly into the poke commands. The A/D card channel addresses for the 4 channels used per step are calculated at the beginning of the program before entering the drive loop, and are also placed directly into the poke commands. Variable names vice constant values were used in the poke commands to further increase speed. This is because it takes much more time to convert a constant to its floating point representation than it does to fetch the value of a variable [Ref. 6]. Due to the above modifications the 90 degree transition time was reduced to 4.8 seconds. Figure 19 is the same type drive routine as that of Figure 18 except that a four step drive loop is used. As would be expected the transit time was cut in half to 2.6 seconds due to the larger step size, however the operation of the drive motor became unstable. At this speed the time to serially deliver the four elements comprising a step approaches the time between steps of 5 msec. It is therefore possible for the inertia of the larger steps (1.9 vs. 0.8 degrees), to carry the rotor past the next intended position before the new step is set up. The drive motor would operate normally for a time and then suddenly begin to oscillate about some position.

```
***  THIRD DRIVE DESIGN USING A/D   ***
*** CARD. HERE EACH DRIVE STEP HAS  ***
***  MEMORY ADDRESS ASSIGNED VICE   ***
*** ACCESSING AN ARRAY AS IN FIRST  ***
*** TWO DESIGNS. TRANSIT TIME FOR   ***
*** 90 DEG TRANSITION WAS REDUCED   ***
***          TO 4.8 SEC.            ***


80     EN = 60
90     DE = 1
100    SL = 4
120    ML = 49280 + (SL * 16)
140    DIM M(4)
160    M1 = ML + 1
180    M2 = ML + 2
200    M3 = ML + 3
220    M4 = ML + 4
240    HI = 255
260    LO = 128
2000   FOR H1 = 1 TO EN
2100   POKE M1,HI:
       POKE M2,LO:
       POKE M3,HI:
       POKE M4,LO
2200   POKE M1,HI:
       POKE M2,LO:
       POKE M3,LO:
       POKE M4,LO
2300   POKE M1,HI:
       POKE M2,LO:
       POKE M3,LO:
       POKE M4,HI
2400   POKE M1,LO:
       POKE M2,LO:
       POKE M3,LO:
       POKE M4,HI
2500   POKE M1,LO:
       POKE M2,HI:
       POKE M3,LO:
       POKE M4,HI
2600   POKE M1,LO:
       POKE M2,HI:
       POKE M3,LO:
       POKE M4,LO
2700   POKE M1,LO:
       POKE M2,HI:
       POKE M3,HI:
       POKE M4,LO
2800   POKE M1,LO:
       POKE M2,LO:
       POKE M3,LO:
       POKE M4,HI
```

Figure 18. 4.8 Second Eight Step Drive Loop

```
***   THIS DRIVE DESIGN USES ONLY    ***
*** FOUR DRIVE STEPS PER LOOP. THE   ***
*** TRANSITION TIME FOR THIS DESIGN ***
***  WAS ONLY 2.6 SEC, HOWEVER THE   ***
***  DRIVE MOTOR OPERATION BECAME    ***
***            UNRELIABLE.           ***


80     EN = 60
90     DE = 1
100    SL = 4
120    ML = 49280 + (SL * 16)
140    DIM M(4)
160    M1 = ML + 1
180    M2 = ML + 2
200    M3 = ML + 3
220    M4 = ML + 4
240    HI = 255
260    LO = 128
2000   FOR H1 = 1 TO EN
2100   POKE M1,LO:
       POKE M2,HI:
       POKE M3,HI:
       POKE M4,LO
2200   POKE M1,LO:
       POKE M2,HI:
       POKE M3,LO:
       POKE M4,HI
2300   POKE M1,HI:
       POKE M2,LO:
       POKE M3,LO:
       POKE M4,HI
2400   POKE M1,HI:
       POKE M2,LO:
       POKE M3,HI:
       POKE M4,LO
2900   NEXT
```

Figure 19. 2.6 Second Four Step Drive Loop

Figure 20 is a drive routine developed to take advantage of the fact that only one of the four step elements changes from one step to the next in an eight step loop. Only the step element that changed was sent to the drive motor. This routine also proved to be highly unstable and was discarded.

The eight step loop of Figure 18 was finally chosen for use in the main sun tracking program because of its speed, stability, and smoother operation. The four step loop even when stabilized by adding delays between the steps still produced a jerky drive motion, while the smaller 0.8 degree steps of the eight step loop caused the motion to smooth out.

C. DESIGN OF THE SIGNAL INPUT ROUTINES

To control the system the Apple computer must be capable of taking in the sensor and limit switch signals as well as driving the motors. To do this the PEEK command in conjunction with the A/D card is used. The analog voltage values of the signals are delivered directly to eight channels of the A/D card.

The card then changes the analog values into their digital equivalents for use by the computer. The range of digital voltage input values is the same as the output value range discussed earlier (0-255 digital for -5V to +5V analog). The PEEK command is of the form VARIABLE NAME = PEEK (A/D

```
***    IN THIS DRIVE DESIGN AN     ***
***    ATTEMPT WAS MADE TO TAKE    ***
***   ADVANTAGE OF THE FACT THAT   ***
*** ONLY ONE OF FOUR LEVELS CHANGE***
*** PER STEP. SO ONLY THE CHANGING***
***   ELEMENT IS POKED EACH STEP.  ***
***    THIS DESIGN PROVED TO BE    ***
*** COMPLETELY UNSTABLE AS A DRIVE***
***            ROUTINE.            ***


390  FOR K = 1 TO 30
400  POKE 49344,255
405  POKE 49345,128
410  POKE 49346,255
415  POKE 49347,128
420  POKE 49346,128
425  POKE 49347,255
430  POKE 49344,128
435  POKE 49345,255
440  POKE 49347,128
445  POKE 49346,255
450  POKE 49345,128
460  NEXT K
```

Figure 20. Drive Routine Varying Single Step Element

CARD CHANNEL ADDRESS). The digital value found at the indicated address is assigned to the variable. With this particular A/D card the PEEK command must be given twice in order to get the correct value. The first time the command is issued the old value stored in the channel is returned, the second time the new sampled value is delivered. Figure 21 is a routine designed to input sensor and limit switch values, and display them on the system monitor.

In this routine the base address M is calculated in line 110 and incremented by the Do Loop counter I to get the eight input channel addresses of the A/D card. These are the same addresses as the eight used for outputting the drive steps. The command used (PEEK or POKE) determines whether the particular address is used for input or output. The input output wiring to and from the A/D card is physically separate (see Figure 14), it is only on the internal computer bus that the the same lines are used for input and output. The table below is included for a quick reference to the A/D card channel use.

CARD ADDRESS USING SLOT 4	CHANNEL NUMBER	INPUT USE	DRIVE STEP ELEMENT
49345	01	ES	H1
49346	02	WS	H2
49347	03	US	H3

```
***   THIS ROUTINE WAS THE FIRST   ***
***  ATTEMPT TO UTILIZE THE INPUT ***
***   SIDE OF THE A/D CARD. ALL    ***
*** SENSOR AND LIMIT SWITCH VALUES***
***  ARE OBTAINED BY USING THE DO ***
***   LOOP. THE VALUES ARE THEN    ***
***   OUTPUT TO THE SCREEN. THIS   ***
***   ROUTINE WAS LATER USED TO    ***
*** OBTAIN SENSOR THRESHOLD VALUES***
***  FOR USE IN THE MAIN PROGRAM   ***
***           DESIGN.              ***
```

```
100  DIM X(8)
110  M = 49280 + (4 * 16)
115  HOME
120  FOR I = 1 TO 8
130  FOR J = 1 TO 2
140  X(I) =  PEEK (M + I)
150  NEXT J
160  NEXT I
200  VTAB 21: PRINT  TAB( 6)"US="X(3)"
     UL="X(7)
210  VTAB 22: PRINT  TAB( 3)"WS="X(2)"
     ES="X(1)" WL="X(6)" EL="X(5)
220  VTAB 23: PRINT  TAB( 6)"DS="X(4)"
     DL="X(8)
400  FOR A = 1 TO 100: NEXT
410  GOTO 120
```

Figure 21. Display Routine

49348	04	DS	H4
49349	05	EL	V1
49350	06	WL	V2
49351	07	UL	V3
49352	08	DL	V4

The J Do Loop executes the PEEK command twice for each of the eight channels determined by the I loop, and assigns the proper value to the array variable X(I). Lines 200-220 provide the screen output, and line 400 is a 0.1 second delay loop added for display clarity.

D. DETERMINATION OF SENSOR VALUES

The next step in the design of the software was to use the display routine to determine the proper sensor threshold values for use in the sun tracking routine. With the routine running the sensors were exposed to a variety of conditions, and the values below were determined.

CONDITION	VALUE	
	ANALOG	DIGITAL
Completely Dark	0 V	128
Exposed to Desk Lamp	0.08 V	130
Facing Away From Sun on Bright Day	0.12 V	131
Directly at Bright Sun	2.34 V	188
4 Sensors Balanced on Bright Sun	0.47 V	140
4 Sensors Balanced on Hazy Sun	0.16 V	132
4 Sensors Balanced on Cloud Covered Sun	0.08 V	130

From the above information it was determined that a cutoff value to use for determining if the sun were out or not would be 130 or less. Limit switch values were determined to be 128 = 0V if not depressed, and 255 = +5V if depressed.

E. FLASHLIGHT FOLLOW ROUTINE

Once the drive and display routines had been developed and expected sensor values had been determined, the next step was to combine them into a working routine. The flashlight follow routine (Appendix A), was developed as an intermediate step before attacking the more complex sun tracking routine. In this routine the sensors are checked continuously to see if any go above the threshold value of 130. If any do then the appropriate drive loop is run. There are four eight step drive loops, one for each direction of travel (UP,DOWN,EAST,WEST). It should be pointed out that by running the loop in the reverse direction the motor will also run in the opposite direction. Table 5 lists the eight step loops for each direction of travel.

At the beginning of each drive loop the four A/D card channels to poke the steps to are determined by adding the appropriate channel value to the base address. For instance L1 = M+5 assigns the address of channel 5 to the variable L1, so that L1-L4 have the addresses of channels 5-8. The L5 and L6 variables are assigned the channel addresses of the limit switch that the system is being driven toward, and the sensor that is involved respectively. Next the limit switch

TABLE 5

EIGHT STEP DRIVE LOOPS

	HORIZONTAL MOTOR A/D CARD CHANNELS 1-4		VERTICAL MOTOR A/D CARD CHANNELS 5-8	
	EAST	WEST	UP	DOWN
STEP 1:	1010	0010	0010	1010
STEP 2:	1000	0110	0110	1000
STEP 3:	1001	0100	0100	1001
STEP 4:	0001	0101	0101	0001
STEP 5:	0101	0001	0001	0101
STEP 6:	0100	1001	1001	0100
STEP 7:	0110	1000	1000	0110
STEP 8:	0010	1010	1010	0010

and sensor values are checked to be sure that both are still within limits. If not the loop is exited, and the program returns to the original sensor checking loop. If both values are still within limits the first two steps of the drive loop are sent to the appropriate drive motor. The limit switch and sensor are again checked, and either the loop is exited or two more steps are taken. This checking and stepping continues until the sensor goes below threshold (the flashlight is removed), or the system runs into the stops (the limit switch). Each of the four drive loops works the same, the only difference is the address values assigned to L1-L6.

Now that all the drive loop, sensor inputs, and limit switches had been successfully combined, the next step was to develop the sun tracking routine.

F. SUN TRACKING PROGRAM

The final step in the design of the controlling software was to develop the actual sun tracking program (Appendix B). Since the program listing is well remarked, only the main points of this program will be discussed. The program consists of four main parts. The first is a tracker calibration routine, the second is a sun location routine, the third is a sun tracking routine, and the fourth is a cloud cover waiting routine.

The calibration routine is included because the tabs that depress the various limit switches have a tendency to

become misaligned. This is important because degrees longitude, and degrees elevation are displayed on the screen. If the system is no longer limited to true east and true west or horizontal and vertical, these output values will be incorrect. When the tracker is calibrated properly it is limited to a transition of 180 degrees between the east and west limit switches, and 90 degrees between the up and down switches. Due to the gearing between the motors and drive structures of the tracker, approximately 1005 steps are required for the east to west, and 510 for the up down transitions. This routine starts the tracker in an upright east facing position, counts the steps required to transition to the west facing and down positions, and then returns to the east facing upright start position. The step count values are checked and if they are outside predetermined limits, an appropriate message is displayed on the screen. The step count values obtained are also divided by the number of degrees in their particular transition to get a steps per degree value that will be used for degrees longitude and elevation calculations in later routines.

It should be noticed that two vice four drive loops are used for the different drive requirements in the sun tracking program. As can be seen in Table 5 the east and down drive loops are the same, as are the west and up loops. Only the channel numbers of the step output lines are different. If the step and sensor/limit switch channel

addresses are determined in controlling logic external to the drive loops, and are assigned to common variables, a single drive loop can be used for two directions (EAST/DOWN or WEST/UP).

The sun location routine is used to obtain a rough lock on before passing control to the sun tracking routine. Starting from the east facing upright position, the system is moved toward the west. The up sensor values are checked and if they remain the same or increase the sensor is going toward the sun. When the values begin to decrease a counter is set and if the old sensor reading is less than the new value three times in a row, the tracker moves back to the position of the first decrease. If the readings are the same the counter stays the same, if the new reading is more than the last the counter is reset. These counters are necessary because the sensor values tend to vary by ±1 quite often. If there are three successive decreases then random value fluctuations can be ruled out.

When the tracker has moved back to the point of maximum sun intensity (the first sensor value decrease), it begins an upward transition. During this transition the up and down values are continually checked. When their values are the same the sun's intensity is equal on both sensors, thus the tracker is locked onto the sun's elevation. Control is now passed to the sun tracking routine. If lock-on is not

achieved in either the horizontal or the vertical transitions, an appropriate message is printed on the screen.

The tracking routine's main function is to ensure that the UP/DOWN sensor values are the same, and that the EAST/WEST sensors are also balanced. The four values do not necessarily have to be the same, only each pair must balance. When this is achieved then the tracker is locked onto the sun. When one sensor of a pair is not equal to the other a counter is set, if the sensors remain unbalanced for a count of five, two drive steps are taken in the direction necessary to rebalance the sensor pair. Again the counter is necessary due to the sensor outputs tendency to vary about a value by ±1. If clouds cover the sun, its intensity becomes too low for the sensors to track, and control is passed to the cloud cover routine.

The cloud cover routine continually checks the up sensor to determine if it goes back above the threshold value (clouds no longer cover the sun). If it does, control is returned to the tracking routine. If the value remains below threshold a counter is incremented once each second. At 10 minutes or a counter value of 600, control is passed back to the sun location routine, which places the tracker back in startup position and waits for the sun to reappear. The 10 minute limit is necessary because after prolonged cloud cover, the sun will move out of position and relocation will be necessary.

As mentioned the program listing (Appendix B), is well remarked and can be traced through for program specifics.

IV. CONCLUSIONS AND RECOMMENDATIONS

Once completed the system performed well with the new computer. The screen/keyboard interaction now available expands the possible system uses. Some possible system enhancements can be made.

A clock card could be added to the Apple that would bring a real time capability to the system. By being able to determine the date and time, a series of calculations could be performed that would give the sun's location. Reference 1 in its chapter on "Terrestrial Solar Radiation," describes the procedure in some detail. Once latitude and elevation values had been calculated for the sun, the tracker could be placed in that position and control passed to the sun tracking routine. This would do away with the need for the sun location routine, and make the initial lock-on much faster. Another use would be in the cloud cover routine where the tracker's position could be updated by the same calculations. Since the tracker's position could now be automatically updated, the system would not have to return to the start up position after the 10 minute time out.

Another enhancement would be to assemble the drive routines in order to increase drive speed. The assembled code would be internal to the system thus preserving the easier to interpret Basic code for user understanding. The

steps could be delivered to the motors much more rapidly than in the Basic form, thus preventing the instability problem encountered earlier with the four step drive loop.

Another idea would be to use the tracker as a positioning device for a larger tracking system. The longitude and elevation position information that is now displayed on the screen could also be sent to a much larger device, thus eliminating the need for sensors on that device. Drive motor commands could also be sent to power amplification devices that would drive the larger positioning motors.

A card could be developed and built to be placed inside the Apple computer that would replace the circuit board currently inside the A/I box. This would reduce the need for much of the current external wiring, as the signals would interface the computer via the internal bus. With the circuit board out of the A/I box the power transistors could be relocated into a much smaller box which would be mounted under the tracker. This would produce a much more compact system.

One last recommendation is to develop a power supply to deliver all the necessary voltages to the system. This would do away with the current requirement for three separate external power supplies.

APPENDIX A

FLASHLIGHT FOLLOW ROUTINE

```
10    REM  "MAIN ROUTINE"
20    REM
30    REM  "FLASHLIGHT FOLLOW"
40    REM  "ROUTINE"
50    REM
60    REM  "SET HIGH AND LOW"
70    REM  "MOTOR DRIVE VALUES"
80    REM  "FOR DRIVE ROUTINES"
90    REM
100   HI = 255
110   LO = 128
120   REM
130   REM  "SET LIMIT SWITCH AND"
140   REM  "SENSOR THRESHOLDS"
150   REM
160   THR = 130
170   CO = 160
180   REM
190   REM  "DETERMINE MEMORY"
200   REM  "START ADDRESS FOR"
210   REM  "PROGRAM USE"
220   REM
230   M = 49280 + (4 * 16)
240   REM
250   REM  "CHECK SENSOR VALUES"
260   REM  "TO DETERMINE IF ANY"
270   REM  "ARE ABOVE THRESHOLD"
280   REM
290   FOR I = 1 TO 4
300   FOR J = 1 TO 2
310   X(I) =  PEEK (M + I)
320   NEXT J
330   NEXT I
340   REM
350   REM  "IF ANY ABOVE"
360   REM  "THRESHOLD GO TO"
370   REM  "APPROPRIATE DRIVE"
380   REM  "SUBROUTINE"
390   REM
400   IF X(3) >  = THR THEN  GOTO 2000
410   IF X(4) >  = THR THEN  GOTO 3000
420   IF X(1) >  = THR THEN  GOTO 4000
430   IF X(2) >  = THR THEN  GOTO 5000
440   GOTO 290
450   REM
```

```
2000  REM  "UP DRIVE SUBROUTINE"
2010  REM
2020  REM  "INITIALIZE  VALUES"
2030  REM  "TO BE USED IN"
2040  REM  "SUBROUTINE"
2050  REM
2060  L1 = M + 5:
      L2 = M + 6:
      L3 = M + 7:
      L4 = M + 8:
      L5 = M + 7:
      L6 = M + 3
2070  REM
2080  REM  "DETERMINE IF ARM"
2090  REM  "IS AGAINST UPPER"
2100  REM  "LIMIT SWITCH OR IF"
2110  REM  "UPPER SENSOR IS"
2120  REM  "STILL ABOVE THRES-"
2130  REM  "HOLD VALUE"
2140  REM
2150  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
2160  REM
2170  REM  "IF SWITCH DEPRESSED"
2180  REM  "OR IF SENSOR BELOW"
2190  REM  "THRESHOLD RETURN TO"
2200  REM  "MAIN LOOP"
2210  REM
2220  IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
2230  REM
2240  REM  "PLUG IN (POKE)"
2250  REM  "VALUES FOR FIRST"
2260  REM  "TWO 0.9 DEG. STEPS"
2270  REM
2280  POKE L1,LO:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
2290  POKE L1,LO:
      POKE L2,HI:
      POKE L3,HI:
      POKE L4,LO
2300  REM
2310  REM  "RECHECK LIMIT"
2320  REM  "SWITCH AND SENSOR"
2330  REM  "VALUES"
2340  REM
2350  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
```

```
        Y2 =  PEEK (L6):
        Y2 =  PEEK (L6)
2360    IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
2370    REM
2380    REM  "MOTOR SETPS THREE"
2390    REM  "AND FOUR"
2400    REM
2410    POKE L1,LO:
        POKE L2,HI:
        POKE L3,LO:
        POKE L4,LO
2420    POKE L1,LO:
        POKE L2,HI:
        POKE L3,LO:
        POKE L4,HI
2430    REM
2440    REM  "RECHECK THRESHOLD"
2450    REM  "VALUES"
2460    REM
2470    Y1 =  PEEK (L5):
        Y1 =  PEEK (L5):
        Y2 =  PEEK (L6):
        Y2 =  PEEK (L6)
2480    IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
2490    REM
2500    REM  "MOTOR STEPS FIVE"
2510    REM  "AND SIX"
2520    REM
2530    POKE L1,LO:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,HI
2540    POKE L1,HI:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,HI
2550    REM
2560    REM  "RECHECK THRESHOLD"
2570    REM  "VALUES"
2580    REM
2590    Y1 =  PEEK (L5):
        Y1 =  PEEK (L5):
        Y2 =  PEEK (L6):
        Y2 =  PEEK (L6)
2600    IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
2610    REM
2620    REM  "MOTOR STEPS SEVEN"
2630    REM  "AND EIGHT"
2640    REM
2650    POKE L1,HI:
        POKE L2,LO:
```

```
      POKE L3,LO:
      POKE L4,LO
2660  POKE L1,HI:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
2670  GOTO 2060
3000  REM  "DOWN DRIVE ROUTINE"
3010  REM
3020  REM  "INITIALIZE  VALUES"
3030  REM  "TO BE USED IN"
3040  REM  "SUBROUTINE"
3050  REM
3060  L1 = M + 5:
      L2 = M + 6:
      L3 = M + 7:
      L4 = M + 8:
      L5 = M + 8:
      L6 = M + 4
3070  REM
3080  REM  "DETERMINE IF ARM"
3090  REM  "IS AGAINST DOWN"
3100  REM  "LIMIT SWITCH OR IF"
3110  REM  "DOWN SENSOR IS"
3120  REM  "STILL ABOVE THRES-"
3130  REM  "HOLD VALUE"
3140  REM
3150  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
3160  REM
3170  REM  "IF SWITCH DEPRESSED"
3180  REM  "OR IF SENSOR BELOW"
3190  REM  "THRESHOLD RETURN TO"
3200  REM  "MAIN LOOP"
3210  REM
3220  IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
3230  REM
3240  REM  "PLUG IN (POKE)"
3250  REM  "VALUES FOR FIRST"
3260  REM  "TWO 0.9 DEG. STEPS"
3270  REM
3280  POKE L1,HI:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
3290  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,LO
```

```
3300  REM
3310  REM  "RECHECK LIMIT"
3320  REM  "SWITCH AND SENSOR"
3330  REM  "VALUES"
3340  REM
3350  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
3360  IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
3370  REM
3380  REM   "MOTOR STEPS THREE"
3390  REM  "AND FOUR"
3400  REM
3410  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,HI
3420  POKE L1,LO:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,HI
3430  REM
3440  REM  "RECHECK THRESHOLD"
3450  REM  "VALUES"
3460  REM
3470  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
3480  IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
3490  REM
3500  REM  "MOTOR STEPS FIVE"
3510  REM  "AND SIX"
3520  REM
3530  POKE L1,LO:
      POKE L2,HI:
      POKE L3,LO:
      POKE L4,HI
3540  POKE L1,LO:
      POKE L2,HI:
      POKE L3,LO:
      POKE L4,LO
3550  REM
3560  REM  "RECHECK THRESHOLD"
3570  REM  "VALUES"
3580  REM
3590  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
```

```
3600  IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
3610  REM
3620  REM  "MOTOR STEPS SEVEN"
3630  REM  "AND EIGHT"
3640  REM
3650  POKE L1,LO:
      POKE L2,HI:
      POKE L3,HI:
      POKE L4,LO
3660  POKE L1,LO:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
3670  GOTO 3060
4000  REM   "EAST DRIVE ROUTINE"
4010  REM
4020  REM  "INITIALIZE  VALUES"
4030  REM  "TO BE USED IN"
4040  REM  "SUBROUTINE"
4050  REM
4060  L1 = M + 1:
      L2 = M + 2:
      L3 = M + 3:
      L4 = M + 4:
      L5 = M + 5:
      L6 = M + 1
4070  REM
4080  REM  "DETERMINE IF ARM"
4090  REM   "IS AGAINST EAST"
4100  REM  "LIMIT SWITCH OR IF"
4110  REM  "EAST SENSOR IS"
4120  REM  "STILL ABOVE THRES-"
4130  REM  "HOLD VALUE"
4140  REM
4150  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
4160  REM
4170  REM  "IF SWITCH DEPRESSED"
4180  REM  "OR IF SENSOR BELOW"
4190  REM  "THRESHOLD RETURN TO"
4200  REM  "MAIN LOOP"
4210  REM
4220  IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
4230  REM
4240  REM  "PLUG IN (POKE)"
4250  REM  "VALUES FOR FIRST"
4260  REM  "TWO 0.9 DEG. STEPS"
4270  REM
4280  POKE L1,HI:
```

```
        POKE L2,LO:
        POKE L3,HI:
        POKE L4,LO
4290    POKE L1,HI:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,LO
4300    REM
4310    REM  "RECHECK LIMIT"
4320    REM  "SWITCH AND SENSOR"
4330    REM  "VALUES"
4340    REM
4350    Y1 =  PEEK (L5):
        Y1 =  PEEK (L5):
        Y2 =  PEEK (L6):
        Y2 =  PEEK (L6)
4360    IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
4370    REM
4380    REM   "MOTOR STEPS THREE"
4390    REM  "AND FOUR"
4400    REM
4410    POKE L1,HI:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,HI
4420    POKE L1,LO:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,HI
4430    REM
4440    REM  "RECHECK THRESHOLD"
4450    REM  "VALUES"
4460    REM
4470    Y1 =  PEEK (L5):
        Y1 =  PEEK (L5):
        Y2 =  PEEK (L6):
        Y2 =  PEEK (L6)
4480    IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
4490    REM
4500    REM  "MOTOR STEPS FIVE"
4510    REM  "AND SIX"
4520    REM
4530    POKE L1,LO:
        POKE L2,HI:
        POKE L3,LO:
        POKE L4,HI
4540    POKE L1,LO:
        POKE L2,HI:
        POKE L3,LO:
        POKE L4,LO
4550    REM
```

```
4560  REM  "RECHECK THRESHOLD"
4570  REM  "VALUES"
4580  REM
4590  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
4600  IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
4610  REM
4620  REM  "MOTOR STEPS SEVEN"
4630  REM  "AND EIGHT"
4640  REM
4650  POKE L1,LO:
      POKE L2,HI:
      POKE L3,HI:
      POKE L4,LO
4660  POKE L1,LO:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
4670  GOTO 4060
5000  REM  "WEST DRIVE ROUTINE"
5010  REM
5020  REM  "INITIALIZE  VALUES"
5030  REM  "TO BE USED IN"
5040  REM  "SUBROUTINE"
5050  REM
5060  L1 = M + 1:
      L2 = M + 2:
      L3 = M + 3:
      L4 = M + 4:
      L5 = M + 6:
      L6 = M + 2
5070  REM
5080  REM  "DETERMINE IF ARM"
5090  REM  "IS AGAINST WEST"
5100  REM  "LIMIT SWITCH OR IF"
5110  REM  "WEST SENSOR IS"
5120  REM  "STILL ABOVE THRES-"
5130  REM  "HOLD VALUE"
5140  REM
5150  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
5160  REM
5170  REM  "IF SWITCH DEPRESSED"
5180  REM  "OR IF SENSOR BELOW"
5190  REM  "THRESHOLD RETURN TO"
5200  REM  "MAIN LOOP"
5210  REM
```

```
5220  IF (Y1 > = C0) OR (Y2 < = THR) THEN  GOTO 280
5230  REM
5240  REM  "PLUG IN (POKE)"
5250  REM  "VALUES FOR FIRST"
5260  REM  "TWO 0.9 DEG. STEPS"
5270  REM
5280  POKE L1,LO:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
5290  POKE L1,LO:
      POKE L2,HI:
      POKE L3,HI:
      POKE L4,LO
5300  REM
5310  REM  "RECHECK LIMIT"
5320  REM  "SWITCH AND SENSOR"
5330  REM  "VALUES"
5340  REM
5350  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
5360  IF (Y1 > = C0) OR (Y2 < = THR) THEN  GOTO 280
5370  REM
5380  REM  "MOTOR SETPS THREE"
5390  REM  "AND FOUR"
5400  REM
5410  POKE L1,LO:
      POKE L2,HI:
      POKE L3,LO:
      POKE L4,LO
5420  POKE L1,LO:
      POKE L2,HI:
      POKE L3,LO:
      POKE L4,HI
5430  REM
5440  REM  "RECHECK THRESHOLD"
5450  REM  "VALUES"
5460  REM
5470  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
5480  IF (Y1 > = C0) OR (Y2 < = THR) THEN  GOTO 280
5490  REM
5500  REM  "MOTOR STEPS FIVE"
5510  REM  "AND SIX"
5520  REM
5530  POKE L1,LO:
      POKE L2,LO:
```

```
      POKE L3,LO:
      POKE L4,HI
5540  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,HI
5550  REM
5560  REM  "RECHECK THRESHOLD"
5570  REM  "VALUES"
5580  REM
5590  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5):
      Y2 =  PEEK (L6):
      Y2 =  PEEK (L6)
5600  IF (Y1 >  = CO) OR (Y2 <  = THR) THEN  GOTO 280
5610  REM
5620  REM  "MOTOR STEPS SEVEN"
5630  REM  "AND EIGHT"
5640  REM
5650  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,LO
5660  POKE L1,HI:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
5670  GOTO 5060
```

APPENDIX B

MAIN SUN TRACKING PROGRAM

```
100  REM ****************************************
110  REM ** THE FOLLOWING IS A PROGRAM FOR SUN **
120  REM ** TRACKING. IT CONSISTS OF FOUR MAIN **
130  REM ** PARTS. (1) A SYSTEM CALIBRATION    **
140  REM ** ROUTINE (2) A SUN LOCATION ROUTINE **
150  REM ** (3) A SUN TRACKING ROUTINE (4) AND **
160  REM ** A CLOUD COVER WAIT ROUTINE.        **
170  REM ****************************************
180  REM
190  REM
200  REM ****************************************
210  REM ***       CALIBRATION ROUTINE        ***
220  REM ****************************************
230  REM
240  REM
250  REM *** CLEAR SCREEN ***
260  HOME
270  REM
280  REM *** PRINT HEADER ON SCREEN ***
290  REM
300  VTAB 2: PRINT "THE NUMBER OF 0.9 DEG. STEPS REQUIRED"
310  VTAB 3: PRINT "TO DRIVE THE SYSTEM THROUGH A COMPLETE"
320  VTAB 4: PRINT "HORIZONTAL OR VERTICAL TRANSITION ARE"
330  VTAB 5: PRINT "COUNTED AND USED TO DETERMINE TRACKING"
340  VTAB 6: PRINT "POSITION, AND CHECK SYSTEM CALIBRATION"
341  REM
342  REM *** DUE TO GEARING DOWN OF     ***
343  REM *** THE DRIVE MOTORS APPROX    ***
344  REM *** 500   0.9DEG STEPS ARE     ***
345  REM *** REQUIRED TO TRANSITION 90 ***
346  REM *** DEGREES.                   ***
347  REM
350  REM
360  REM *** CALCULATE MEMORY LOCATION ***
370  REM *** POINTER FOR A/D CARD.     ***
380  REM
390  M = 49280 + (4 * 16)
400  REM
410  REM *** SET VALUE TO DETERMINE IF ***
420  REM *** LIMIT SWITCH IS DEPRESSED ***
430  REM
440  CO = 160
450  REM
```

```
460  REM *** SET VALUES FOR STEP POKES ***
470  REM *** TO A/D CARD,127=0V 255=5V ***
480  REM
490  HI = 255
500  LO = 127
510  REM
520  REM *** INITIALIZE COUNTERS TO BE ***
530  REM *** USED IN SUN LOCATION RTN. ***
540  REM
550  AB = 0:AC = 0
560  REM
570  REM *** THESE TWO CALLS INITIALIZE***
580  REM *** THE SEEKER BY PLACING IT   ***
590  REM *** IN AN UPRIGHT EAST FACING ***
600  REM *** POSITION                  ***
610  REM
620  VTAB 8: PRINT "PLACE IN UPRIGHT POSITION"
630  REM
640  REM *** PASS TO DRIVE ROUTINES THE***
650  REM *** MEMORY LOCATIONS OF THE   ***
660  REM *** A/D CARD TO POKE STEP     ***
670  REM *** VALUES TO (L1-L4). ALSO   ***
680  REM *** MEMORY LOCATION OF LIMIT  ***
690  REM *** SWITCH TO CHECK FOR       ***
700  REM *** DEPRESSION AT END OF RUN  ***
710  REM *** (L5), AND PASS VALUE TO   ***
720  REM *** TO TELL ROUTINE IF IT IS  ***
730  REM *** DRIVING UP OR EAST (L6)   ***
740  REM
750  L1 = M + 5:
     L2 = M + 6:
     L3 = M + 7:
     L4 = M + 8:
     L5 = M + 8:
     L6 = 1
760  GOTO 1810
770  REM
780  REM *** DRIVE TO EAST. L1-L6 SAME ***
790  REM *** USE AS ABOVE.             ***
800  REM
810  VTAB 8: PRINT "SET FACING EAST                      "
820  L1 = M + 1:
     L2 = M + 2:
     L3 = M + 3:
     L4 = M + 4:
     L5 = M + 5:
     L6 = 2
830  GOTO 1810
840  REM
850  REM *** THESE TWO CALLS CAUSE THE ***
860  REM *** NUMBER OF STEPS FOR ONE   ***
```

```
870  REM *** TRANSITION WEST AND ONE    ***
880  REM *** TRANSITION TO THE DOWN     ***
890  REM *** POSITION TO BE COUNTED     ***
900  REM
910  VTAB 8: PRINT "WEST COUNTING RUN"
920  REM
930  REM *** EAST COUNTING RUN. PASS    ***
940  REM *** TO DRIVE ROUTINE STEP      ***
950  REM *** POKE MEMORY LOCATIONS      ***
960  REM *** (L1-L4), LIMIT SWITCH (L5)***
970  REM *** WHERE TO RETURN WHEN       ***
980  REM *** FINISH COUNTING RUN (L6)   ***
990  REM *** AND INDICATOR OF WEST OR   ***
1000  REM *** UP COUNTING RUN (L7),      ***
1010  REM
1020  L1 = M + 1:
      L2 = M + 2:
      L3 = M + 3:
      L4 = M + 4:
      L5 = M + 6:
      L6 = 1:
      L7 = 200
1030  GOTO 2320
1040  REM
1050  REM *** PRINT OUT NUMBER OF STEPS ***
1060  REM *** FOR EAST TO WEST TRANSI-  ***
1070  REM *** TION (LN), AND STEPS PER  ***
1080  REM *** DEGREE (LD).              ***
1090  REM
1100  VTAB 14: PRINT "LONGITUDE COUNT="LN
1110  LD = LN / 180
1120  REM
1130  REM *** LIMIT SCREEN DISPLAY TO   ***
1140  REM *** TWO DECIMAL POINT ACCURACY***
1150  REM
1160  LD =  INT (LD * 100 + .5) / 100
1170  VTAB 18: PRINT "STEPS/DEG. LONG="LD
1180  REM
1190  REM *** COUNTING RUN FROM UPRIGHT ***
1200  REM *** TO DOWN POSITION          ***
1210  REM
1220  VTAB 8: PRINT "VERT COUNTING RUN"
1230  REM
1240  REM *** PASS SAME INFORMATION AS  ***
1250  REM *** AS ABOVE TO DRIVE ROUTINE ***
1260  REM
1270  L1 = M + 5:
      L2 = M + 6:
      L3 = M + 7:
      L4 = M + 8:
      L5 = M + 7:
```

```
         L6 = 2:
         L7 = 155
1280     GOTO 2320
1290     REM
1300     REM *** PRINTOUT SAME AS ABOVE     ***
1310     REM *** FOR STEPS FROM UP TO DOWN ***
1320     REM *** POSITION (LT), AND STEPS   ***
1330     REM *** PER DEGREE (LE).           ***
1340     REM
1350     VTAB 15: PRINT "LATITUDE COUNT ="LT
1360     LE = LT / 90
1370     LE =  INT (LE * 100 + .5) / 100
1380     VTAB 19: PRINT "STEPS/DEG. LAT ="LE
1390     REM
1400     REM *** THESE TWO CALLS RETURN     ***
1410     REM *** THE SEEKER TO THE UPRIGHT ***
1420     REM *** AND EAST FACING POSITION  ***
1430     REM *** BEFORE GOING TO THE SUN    ***
1440     REM *** LOCATION ROUTINE           ***
1450     REM
1460     VTAB 8: PRINT "RETURN TO START POSITION"
1470     L1 = M + 5:
         L2 = M + 6:
         L3 = M + 7:
         L4 = M + 8:
         L5 = M + 8:
         L6 = 3
1480     GOTO 1810
1490     L1 = M + 1:
         L2 = M + 2:
         L3 = M + 3:
         L4 = M + 4:
         L5 = M + 5:
         L6 = 4
1500     GOTO 1810
1510     HOME
1520     REM
1530     REM *** DETERMINE IF THE NUMBER    ***
1540     REM *** OF STEPS FOR EACH TRANSI- ***
1550     REM *** TION IS OUT OF LIMITS, IF ***
1560     REM *** IT IS PRINT APPROPRIATE    ***
1570     REM *** ERROR MESSAGE.             ***
1580     REM
1590     IF (LN < 990) OR (LN > 1020) THEN  VTAB 10:
         PRINT "HORIZONTAL PARAMETERS OUT OF RANGE": VTAB 11:
         PRINT "CHECK LIMIT SWITCH ALLIGNMENT": GOTO 1660
1600     IF (LT < 490) OR (LT > 520) THEN  VTAB 12:
         PRINT "VERTICAL PARAMETERS OUT OF RANGE": VTAB 13:
         PRINT "CHECK LIMIT SWITCH ALLIGNMENT": GOTO 1660
1610     GOTO 5090
1620     REM
```

```
1630  REM *** DETERMINE IF WANT TO       ***
1640  REM *** CONTINUE WHEN OUT OF LIMIT***
1650  REM
1660  VTAB 15: INPUT "DO YOU WANT TO CONTINUE?(Y/N)";K$
1670  IF K$ = "N" THEN  PRINT  CHR$ (4);"RUN HELLO"
1680  IF K$ = "Y" THEN  GOTO 5090
1690  REM
1700  REM *** DRIVE ROUTINE FOR EAST AND***
1710  REM *** UP INITIALIZATION.         ***
1720  REM
1730  REM
1740  REM
1750  REM *** CHECK LIMIT SWITCH AS      ***
1760  REM *** DETERMINED BY L5, TO       ***
1770  REM *** SEE IF SEEKER ARM IS       ***
1780  REM *** AGAINST IT. IF IT IS JUMP ***
1790  REM *** OUT OF THE ROUTINE.        ***
1800  REM
1810  Y1 =  PEEK (L5):Y1 =  PEEK (L5)
1820  IF Y1 > CO THEN  GOTO 2220
1830  REM
1840  REM *** VALUES TO POKE INTO D/A    ***
1850  REM *** CARD MEMORY LOCATIONS      ***
1860  REM *** (L1-L4) TO PRODUCE MOTOR   ***
1870  REM *** STEP. REPEAT FOR 8 STEP    ***
1880  REM *** CONTINUOUS LOOP.           ***
1890  REM
1900  POKE L1,HI:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
1910  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5)
1920  IF Y1 > CO THEN  GOTO 2220
1930  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,LO
1940  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5)
1950  IF Y1 > CO THEN  GOTO 2220
1960  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,HI
1970  Y1 =  PEEK (L5):
      Y1 =  PEEK (L5)
1980  IF Y1 > CO THEN  GOTO 2220
1990  POKE L1,LO:
      POKE L2,LO:
      POKE L3,LO:
```

```
     POKE L4,HI
2000 Y1 =  PEEK (L5):
     Y1 =  PEEK (L5)
2010 IF Y1 > CO THEN  GOTO 2220
2020 POKE L1,LO:
     POKE L2,HI:
     POKE L3,LO:
     POKE L4,HI
2030 Y1 =  PEEK (L5):
     Y1 =  PEEK (L5)
2040 IF Y1 > CO THEN  GOTO 2220
2050 POKE L1,LO:
     POKE L2,HI:
     POKE L3,LO:
     POKE L4,LO
2060 Y1 =  PEEK (L5):
     Y1 =  PEEK (L5)
2070 IF Y1 > CO THEN  GOTO 2220
2080 POKE L1,LO:
     POKE L2,HI:
     POKE L3,HI:
     POKE L4,LO
2090 Y1 =  PEEK (L5):
     Y1 =  PEEK (L5)
2100 IF Y1 > CO THEN  GOTO 2220
2110 POKE L1,LO:
     POKE L2,LO:
     POKE L3,HI:
     POKE L4,LO
2120 REM
2130 REM *** RETURN TO STEP ONE          ***
2140 REM
2150 GOTO 1810
2160 REM
2170 REM *** RETURN TO THE CORECT        ***
2180 REM *** PORTION OF THE CONTROL      ***
2190 REM *** SECTION, AS DETERMINED      ***
2200 REM *** BY L6                       ***
2210 REM
2220 ON L6 GOTO 810,910,1490,1510
2230 REM
2240 REM
2250 REM *** WEST AND DOWN COUNTING      ***
2260 REM *** DRIVE ROUTINE.              ***
2270 REM
2280 REM
2290 REM
2300 REM *** INITIALIZE COUNTER (N)      ***
2310 REM
2320 N = 0
2330 REM
```

```
2340  REM *** STEP ONE OF EIGHT           ***
2350  REM
2360  POKE L1,LO:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
2370  REM
2380  REM *** INCRIMENT COUNTER           ***
2390  REM
2400  N = N + 1
2410  REM
2420  REM *** PRINT COUNT VALUE AND       ***
2430  REM *** ASSIGN IT TO CORRECT        ***
2440  REM *** VARIABLE AS DETERMINED      ***
2450  REM *** BY L7                       ***
2460  REM
2470  IF L7 = 200 THEN  VTAB 10:
      PRINT "HORIZCT="N:LN = N
2480  IF L7 = 155 THEN  VTAB 12:
      PRINT "VERTCT ="N:LT = N
2490  POKE L1,LO:
      POKE L2,HI:
      POKE L3,HI:
      POKE L4,LO
2500  REM
2510  REM *** CHECK THE LIMIT SWITCH      ***
2520  REM *** ASSIGNED BY L5. IF THE      ***
2530  REM *** SEEKER IS AGAINST IT EXIT ***
2540  REM *** THE DRIVE ROUTINE.          ***
2550  REM *** NOTE:THE TASKS ARE DIVIDED***
2560  REM *** AND ASSIGNED TO EVERY       ***
2570  REM *** OTHER STEP FOR DRIVE SPEED***
2580  REM
2590  Y1 =  PEEK (L5)
2600  Y1 =  PEEK (L5)
2610  IF Y1 >  = CO THEN  GOTO 3050
2620  N = N + 1
2630  REM
2640  REM *** CONTINUE FOR EIGHT STEP     ***
2650  REM *** LOOP.                       ***
2660  REM
2670  POKE L1,LO:
      POKE L2,HI:
      POKE L3,LO:
      POKE L4,LO
2680  N = N + 1
2690  IF L7 = 200 THEN  VTAB 10:
      PRINT "HORIZCT="N:LN = N
2700  IF L7 = 155 THEN  VTAB 12:
      PRINT "VERTCT ="N:LT = N
2710  POKE L1,LO:
```

```
     POKE L2,HI:
     POKE L3,LO:
     POKE L4,HI
2720 Y1 =  PEEK (L5)
2730 Y1 =  PEEK (L5)
2740 IF Y1 >  = CO THEN  GOTO 3050
2750 N = N + 1
2760 POKE L1,LO:
     POKE L2,LO:
     POKE L3,LO:
     POKE L4,HI
2770 N = N + 1
2780 IF L7 = 200 THEN  VTAB 10:
     PRINT "HORIZCT="N:LN = N
2790 IF L7 = 155 THEN  VTAB 12:
     PRINT "VERTCT ="N:LT = N
2800 POKE L1,HI:
     POKE L2,LO:
     POKE L3,LO:
     POKE L4,HI
2810 Y1 =  PEEK (L5)
2820 Y1 =  PEEK (L5)
2830 IF Y1 >  = CO THEN  GOTO 3050
2840 N = N + 1
2850 POKE L1,HI:
     POKE L2,LO:
     POKE L3,LO:
     POKE L4,LO
2860 N = N + 1
2870 IF L7 = 200 THEN  VTAB 10:
     PRINT "HORIZCT="N:LN = N
2880 IF L7 = 155 THEN  VTAB 12:
     PRINT "VERTCT ="N:LT = N
2890 POKE L1,HI:
     POKE L2,LO:
     POKE L3,HI:
     POKE L4;LO
2900 Y1 =  PEEK (L5)
2910 Y1 =  PEEK (L5)
2920 IF Y1 >  = CO THEN  GOTO 3050
2930 N = N + 1
2940 REM
2950 REM *** RETURN TO STEP ONE          ***
2960 REM
2970 GOTO 2360
2980 REM
2990 REM *** WHEN WEST COUNTING RUN      ***
3000 REM *** COMPLETE SWITCH TO DOWN     ***
3010 REM *** COUNTING RUN. WHEN COUNT    ***
3020 REM *** RUNS COMPLETE RETURN TO     ***
3030 REM *** EAST/UP START POSITION      ***
```

```
3040  REM
3050  ON L6 GOTO 1100,1350

5000  REM
5005  REM
5010  REM ****************************************
5015  REM **         SUN LOCATION ROUTINE        **
5020  REM ****************************************
5025  REM
5030  REM
5035  REM *** THIS ROUTINE LOCATES THE  ***
5040  REM *** SUN IN A GENERAL AREA AND ***
5045  REM *** PASSES CONTROL TO THE SUN ***
5050  REM *** TRACKING ROUTINE FOR FINE ***
5055  REM *** ADJUSTING AND LOCK ON     ***
5060  REM *** FOLLOWING.                ***
5065  REM
5070  REM
5075  REM
5080  REM *** INITIALIZE COUNTERS       ***
5085  REM
5090  DH = 0
5095  Z = 0
5100  G = 0
5105  C2 = 0
5110  HOME
5115  REM
5120  REM *** IF FAIL TO LOCATE THE SUN ***
5125  REM *** AFTER TWO TRYS GO TO      ***
5130  REM *** ERROR MESSAGE.            ***
5135  REM
5140  IF AB = 2 GOTO 6025
5145  AB = AB + 1
5150  VTAB 2: PRINT "THIS ROUTINE FINDS THE SUN'S POSITION"
5155  VTAB 3: PRINT "AND PASSES CONTROL TO SUN TRACKING"
5160  VTAB 4: PRINT "ROUTINES"
5165  REM
5168  REM *** A/D CARD MEMORY LOCA-     ***
5170  REM *** TIONS FOR DRIVE STEPS     ***
5175  REM
5180  L1 = M + 1:
      L2 = M + 2:
      L3 = M + 3:
      L4 = M + 4
5185  REM
5190  REM *** CHECK UPSENSOR VALUE IF   ***
5195  REM *** GREATER THAN CUTOFF VALUE ***
5200  REM *** GO TO SUN LOCATION LOGIC  ***
5205  REM *** IF NOT CONTINUE TO LOOP   ***
5210  REM
5215  C2 =  PEEK (M + 3):
```

```
      C2 =  PEEK (M + 3)
5220  IF C2 >  = 130 THEN  GOTO 5250
5225  VTAB 6: PRINT "US="C2
5230  GOTO 5215
5235  REM
5240  REM ***      SUN LOCATION LOGIC     ***
5245  REM
5250  VTAB 9: PRINT "EAST=0 DEG:SOUTH=90 DEG:WEST=180 DEG
5255  REM
5260  REM *** FIRST STEP                  ***
5265  REM
5270  POKE L1,LO:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
5275  REM
5280  REM *** CHECK UPSENSOR (C2), AND    ***
5285  REM *** WEST LIMIT SWITCH (LW),     ***
5290  REM *** VALUES.                     ***
5295  REM
5300  C2 =  PEEK (M + 3):
      C2 =  PEEK (M + 3)
5305  LW =  PEEK (M + 6):
      LW =  PEEK (M + 6)
5310  REM
5315  REM *** PRINT UPSENSOR VALUE ON     ***
5320  REM *** SCREEN, ENSURE SUN BRIGHT   ***
5325  REM *** ENOUGH (C2>131), THAT ARM   ***
5330  REM *** IS NOT AGAINST WEST LIMIT   ***
5335  REM *** SWITCH (LW<160), AND        ***
5340  REM *** INCRIMENT DEGREES HORIZ.    ***
5345  REM *** COUNTER  (DH)               ***
5350  REM
5355  VTAB 6: PRINT "UPSENSOR READING ="C2
5360  IF C2 < 131 THEN  GOTO 5945
5365  IF LW > 160 THEN  GOTO 5985
5370  DH = DH + 1
5375  REM
5380  REM *** SECOND STEP                 ***
5385  REM
5390  POKE L1,LO:
      POKE L2,HI:
      POKE L3,HI:
      POKE L4,LO
5395  REM
5400  REM *** IF OF UPSENSOR OBTAINED     ***
5405  REM *** THIS TIME (C2) IS GREATER   ***
5410  REM *** THAN THE VALUE OBTAINED     ***
5415  REM *** LAST TIME (C1), ZERO THE    ***
5420  REM *** COUNTER BECAUSE STILL       ***
5425  REM *** HEADING TOWARD THE SUN      ***
```

```
5430  REM
5435  IF C2 > C1 THEN Z = 0:G = 0
5440  REM
5445  REM *** IF CURRENT VALUE LESS      ***
5450  REM *** THAN LAST VALUE INCRIMENT  ***
5455  REM *** COUNTER (Z), AND STEPS     ***
5460  REM *** TAKEN SINCE MAX VALUE      ***
5465  REM *** COUNTER (G).               ***
5470  REM
5475  IF C2 < C1 THEN Z = Z + 1:G = G + 2
5480  REM
5485  REM *** CONTINUE COUNTING STEPS    ***
5490  REM *** SINCE PASSED MAX VALUE     ***
5495  REM *** OF UPSENSOR.               ***
5500  REM
5505  IF (C2 = C1) AND (Z > 0) THEN G = G + 2
5510  REM
5515  REM *** REPLACE PREVIOUS READING   ***
5520  REM *** WITH CURRENT READING FOR   ***
5525  REM *** NEXT CHECK.                ***
5530  REM
5535  C1 = C2
5540  REM
5545  REM *** IF CURRENT READING WAS     ***
5550  REM *** LESS THAN PREVIOUS READING***
5555  REM *** FOR THREE CONSECUTIVE      ***
5560  REM *** CHECKS, THEN ARE GOING     ***
5565  REM *** AWAY FROM SUN. GO BACK TO ***
5570  REM *** WHERE FIRST C2<C1 OCCURED ***
5575  REM *** (G) STEPS AGO.             ***
5580  REM
5585  IF Z = 3 THEN AB = 0: GOTO 6090
5590  REM
5595  REM *** INCRIMENT DEGREES HORIZ.   ***
5600  REM *** COUNTER (DH). REPEAT ABOVE***
5605  REM *** LOGIC ON ALTERNATE STEP    ***
5610  REM *** BASIS FOR REMAINING STEPS ***
5615  REM *** OF EIGHT STEP DRIVE LOOP   ***
5620  REM
5625  DH = DH + 1
5630  POKE L1,LO:
      POKE L2,HI:
      POKE L3,LO:
      POKE L4,LO
5635  C2 =  PEEK (M + 3):
      C2 =  PEEK (M + 3)
5640  LW =  PEEK (M + 6):
      LW =  PEEK (M + 6)
5645  VTAB 6: PRINT "UPSENSOR READING ="C2
5650  IF C2 < 131 THEN  GOTO 5945
5655  IF LW > 160 THEN  GOTO 5985
```

```
5660  X1 = DH / LD
5665  DH = DH + 1
5670  POKE L1,LO:
      POKE L2,HI:
      POKE L3,LO:
      POKE L4,HI
5675  IF C2 > C1 THEN Z = 0:G = 0
5680  IF C2 < C1 THEN Z = Z + 1:G = G + 2
5685  IF (C2 = C1) AND (Z > 0) THEN G = G + 2
5690  C1 = C2
5695  IF Z = 3 THEN AB = 0: GOTO 6090
5700  DH = DH + 1
5705  REM
5710  REM *** SET UP FOR DEGREES LONG.  ***
5715  REM *** PRINTOUT WITH ONE DECIMAL ***
5720  REM *** PLACE ACCURACY.           ***
5725  REM
5730  X1 =  INT (X1 * 10 + .5) / 10
5735  POKE L1,LO:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,HI
5740  C2 =  PEEK (M + 3):
      C2 =  PEEK (M + 3)
5745  LW =  PEEK (M + 6):
      LW =  PEEK (M + 6)
5750  VTAB 6: PRINT "UPSENSOR READING ="C2
5755  IF C2 < 131 THEN  GOTO 5945
5760  IF LW > 160 THEN  GOTO 5985
5765  VTAB 8: PRINT "DEGREES LONGITUDE ="X1
5770  DH = DH + 1
5775  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,HI
5780  IF C2 > C1 THEN Z = 0:G = 0
5785  IF C2 < C1 THEN Z = Z + 1:G = G + 2
5790  IF (C2 = C1) AND (Z > 0) THEN G = G + 2
5795  C1 = C2
5800  IF Z = 3 THEN AB = 0: GOTO 6090
5805  DH = DH + 1
5810  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,LO
5815  C2 =  PEEK (M + 3):
      C2 =  PEEK (M + 3)
5820  LW =  PEEK (M + 6):
      LW =  PEEK (M + 6)
5825  VTAB 6: PRINT "UPSENSOR READING ="C2
5830  IF C2 < 131 THEN  GOTO 5945
```

```
5835  IF LW > 160 THEN  GOTO 5985
5840  DH = DH + 1
5845  POKE L1,HI:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
5850  IF C2 > C1 THEN Z = 0:G = 0
5855  IF C2 < C1 THEN Z = Z + 1:G = G + 2
5860  IF (C2 = C1) AND (Z > 0) THEN G = G + 2
5865  C1 = C2
5870  IF Z = 3 THEN AB = 3: GOTO 6090
5875  DH = DH + 1
5880  REM
5885  REM *** RETURN TO STEP ONE        ***
5890  REM
5895  GOTO 5270
5900  REM
5905  REM *** IF UPSENSOR GOES BELOW    ***
5910  REM *** THRESHOLD RETURN TO START ***
5915  REM *** POSITION. USE FLASHING    ***
5920  REM *** MESSAGE. REZERO COUNTER   ***
5925  REM *** (AB) SINCE SUN LOSS DUE   ***
5930  REM *** TO CLOUD COVER IN NORMAL  ***
5935  REM *** OCCURANCE.                ***
5940  REM
5945  VTAB 12: FLASH :
      PRINT "SUN INTENSITY BELOW THRESHOLD VALUE":
      VTAB 13: PRINT "RETURNING TO START UP POSITION":
      NORMAL :AB = 0: GOTO 1470
5950  REM
5955  REM *** IF TRANSITION FROM EAST TO***
5960  REM *** WEST WITHOUT ACHIEVING    ***
5965  REM *** LOCKON, RETURN TO STARTUP ***
5970  REM *** POSITION, BUT DO NOT RESET***
5975  REM *** COUNTER (AB).             ***
5980  REM
5985  VTAB 12: FLASH :
      PRINT "REACHED WEST LIMIT WITHOUT FINDING":
      VTAB 13: PRINT "ACCEPTABLE LOCK ON CRITERIA, RESET":
      NORMAL : GOTO 1470
5990  REM
5995  REM *** IF FAIL TO FIND SUN AFTER ***
6000  REM *** TWO EAST TO WEST TRYS,    ***
6005  REM *** PRINT ERROR MESSAGE AND   ***
6010  REM *** DETERMINE IF WANT TO      ***
6015  REM *** CONTINUE TRYING.          ***
6020  REM
6025  VTAB 16: FLASH :
      PRINT "UNABLE TO LOCATE SUN LONGITUDE"
6030  VTAB 17: PRINT "AFTER TWO TRYS. SUN PROBABLY"
6035  VTAB 18: PRINT "SETTING TOO FAR WEST": NORMAL
```

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6040  VTAB 20: INPUT "WANT TO TRY AGAIN(Y/N)?";K$
6045  IF K$ = "Y" THEN AB = 0: HOME : GOTO 1460
6050  IF K$ = "N" THEN  PRINT  CHR$ (4);"RUN HELLO"
6055  REM
6060  REM ***    BACKUP STEP SEQUENCE    ***
6065  REM
6070  REM *** RETURN TO POSITION WHERE   ***
6075  REM *** SUN INTENSITY FIRST BEGAN ***
6080  REM *** TO DROP OFF (G) STEPS AGO ***
6085  REM
6090  POKE L1,HI:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
6095  GOSUB 6205
6100  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,LO
6105  GOSUB 6205
6110  POKE L1,HI:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,HI
6115  GOSUB 6205
6120  POKE L1,LO:
      POKE L2,LO:
      POKE L3,LO:
      POKE L4,HI
6125  GOSUB 6205
6130  POKE L1,LO:
      POKE L2,HI:
      POKE L3,LO:
      POKE L4,HI
6135  GOSUB 6205
6140  POKE L1,LO:
      POKE L2,HI:
      POKE L3,LO:
      POKE L4,LO
6145  GOSUB 6205
6150  POKE L1,LO:
      POKE L2,HI:
      POKE L3,HI:
      POKE L4,LO
6155  GOSUB 6205
6160  POKE L1,LO:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
6165  GOSUB 6205
6170  GOTO 6090
```

```
6175  REM
6180  REM *** SUBROUTINE TO DECRIMENT   ***
6185  REM *** (G) COUNTER, AND DEGREES  ***
6190  REM *** HORIZONTAL COUNT AS       ***
6195  REM *** BACKUP.                   ***
6200  REM
6205  IF G = 0 THEN AC = 0: GOTO 6260
6210  G = G - 1
6215  DH = DH - 1
6220  RETURN.
6225  REM
6230  REM *** THIS PORTION OF THE SUN   ***
6235  REM *** LOCATION SECTION GETS AN  ***
6240  REM *** ELEVATION LOCKON PRIOR TO ***
6245  REM *** PASSING CONTROL TO THE    ***
6250  REM *** TRACKING SECTION.         ***
6255  REM
6260  DV = 0
6265  REM
6270  REM *** IF GO THROUGH ELEVATION   ***
6275  REM *** TRANSITION TWICE WITHOUT  ***
6280  REM *** ACHIEVING LOCKON, PRINT   ***
6285  REM *** ERROR MESSAGE.            ***
6290  REM
6295  IF AC = 2 THEN  GOTO 5365
6300  AC = AC + 1
6305  HOME
6310  VTAB 2: PRINT "NOW LOCKING ONTO SUN'S ELEVATION"
6315  REM
6320  REM *** PRINT LONGITUDE VALUE     ***
6325  REM *** FOUND IN PREVIOUS ROUTINE ***
6330  REM *** WITH ONE DECIMAL POINT    ***
6335  REM *** ACCURACY.                 ***
6340  REM
6345  X1 = DH / LD
6350  X1 =  INT (X1 * 10 + .5) / 10
6355  VTAB 4: PRINT "SUN LONGITUDE ="X1
6360  VTAB 5: PRINT "EAST=0 DEG SOUTH=90 DEG WEST =180 DEG"
6365  REM
6370  REM *** SET MEMORY LOCATIONS FOR  ***
6375  REM *** DRIVE ROUTINE.            ***
6380  REM
6385  L1 = M + 5:
      L2 = M + 6:
      L3 = M + 7:
      L4 = M + 8
6390  POKE L1,LO:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
6395  REM
```

```
6400  REM *** GET VALUES OF UPSENSOR(C3)***
6405  REM *** DOWN SENSOR (C4), AND      ***
6410  REM *** UP LIMIT SWITCH (LU)       ***
6415  REM
6420  C3 =  PEEK (M + 3):
      C3 =  PEEK (M + 3)
6425  C4 =  PEEK (M + 4):
      C4 =  PEEK (M + 4)
6430  LU =  PEEK (M + 7):
      LU =  PEEK (M + 7)
6435  REM
6440  REM *** IF UPSENSOR (C3) BELOW     ***
6445  REM *** SUNLIGHT THRESHOLD, OR HIT***
6450  REM *** UPLIMIT SWITCH, EXIT DRIVE***
6455  REM *** LOOP.                      ***
6460  REM
6465  IF C3 < 131 THEN  GOTO 6920
6470  IF LU > 160 THEN  GOTO 6950
6475  REM
6480  REM *** INCRIMENT DEGREES ELEVA-   ***
6485  REM *** TION COUNTER (DV)          ***
6490  REM
6495  DV = DV + 1
6500  REM
6505  REM *** STEP TWO                   ***
6510  REM
6515  POKE L1,LO:
      POKE L2,HI:
      POKE L3,HI:
      POKE L4,LO
6520  REM
6525  REM *** IF ACHIEVE BALANCE BETWEEN***
6530  REM *** UPPER AND LOWER SENSOR TO ***
6535  REM *** WITHIN ONE UNIT, GO TO     ***
6540  REM *** SUN TRACKING ROUTINE.      ***
6545  REM
6550  IF C3 = C4 THEN  GOTO 8060
6555  IF (C3 = C4 + 1) OR (C3 = C4 - 1) THEN  GOTO 8060
6560  DV = DV + 1
6565  REM
6570  REM *** CALCULATE DEGREES ELEV.    ***
6575  REM *** BY DIVIDING THE COUNTER    ***
6580  REM *** VALUE (DV) BY STEPS PER    ***
6585  REM *** DEGREE ELEVATION (LE),     ***
6590  REM *** DETERMINED IN CALIBRATION ***
6595  REM *** ROUTINE. REPEAT ABOVE      ***
6600  REM *** LOGIC FOR REMAINING STEPS ***
6605  REM
6610  X2 = DV / LE
6615  POKE L1,LO:
      POKE L2,HI:
```

```
       POKE L3,LO:
       POKE L4,LO
6620   C3 =  PEEK (M + 3):
       C3 =  PEEK (M + 3)
6625   C4 =  PEEK (M + 4):
       C4 =  PEEK (M + 4)
6630   LU =  PEEK (M + 7):
       LU =  PEEK (M + 7)
6635   IF C3 < 131 THEN  GOTO 6920
6640   IF LU > 160 THEN  GOTO 6950
6645   DV = DV + 1
6650   POKE L1,LO:
       POKE L2,HI:
       POKE L3,LO:
       POKE L4,HI
6655   IF C3 = C4 THEN  GOTO 8060
6660   IF (C3 = C4 + 1) OR (C3 = C4 - 1) THEN  GOTO 8060
6665   DV = DV + 1
6670   X2 =  INT (X2 * 10 + .5) / 10
6675   POKE L1,LO:
       POKE L2,LO:
       POKE L3,LO:
       POKE L4,HI
6680   C3 =  PEEK (M + 3):
       C3 =  PEEK (M + 3)
6685   C4 =  PEEK (M + 4):
       C4 =  PEEK (M + 4)
6690   LU =  PEEK (M + 7):
       LU =  PEEK (M + 7)
6695   IF C3 < 131 THEN  GOTO 6920
6700   IF LU > 160 THEN  GOTO 6950
6705   DV = DV + 1
6710   POKE L1,HI:
       POKE L2,LO:
       POKE L3,LO:
       POKE L4,HI
6715   IF C3 = C4 THEN  GOTO 8060
6720   IF (C3 = C4 + 1) OR (C3 = C4 - 1) THEN  GOTO 8060
6725   DV = DV + 1
6730   REM
6735   REM *** PRINT DEGREES ELEVATION    ***
6740   REM *** ONLY ONCE PER EIGHT STEP   ***
6745   REM *** LOOP DUE TO SPEED          ***
6750   REM *** CONSIDERATIONS.            ***
6755   REM
6760   VTAB 7: PRINT "DEGREES ELEVATION ="X2" DEG"
6765   POKE L1,HI:
       POKE L2,LO:
       POKE L3,LO:
       POKE L4,LO
6770   C3 =  PEEK (M + 3):
```

```
      C3 =  PEEK (M + 3)
6775  C4 =  PEEK (M + 4):
      C4 =  PEEK (M + 4)
6780  LU =  PEEK (M + 7):
      LU =  PEEK (M + 7)
6785  IF C3 < 131 THEN  GOTO 6920
6790  IF LU > 160 THEN  GOTO 6950
6795  DV = DV + 1
6800  POKE L1,HI:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
6805  IF C3 = C4 THEN  GOTO 8060
6810  IF (C3 = C4 + 1) OR (C3 = C4 - 1) THEN  GOTO 8060
6815  DV = DV + 1
6820  GOTO 6390
6825  REM
6830  REM *** PRINT ERROR MESSAGE IF     ***
6835  REM *** HAVENT ACHIEVED LOCKON     ***
6840  REM *** AFTER TWO ATTEMPTS, AND    ***
6845  REM *** DETERMINE IF WANT TO       ***
6850  REM *** CONTINUE.                  ***
6855  REM
6860  VTAB 16: FLASH :
      PRINT "UNABLE TO ACHIEVE SENSOR BALANCE AFTER"
6865  VTAB 17:
      PRINT "TWO ATTEMPTS. POSSIBLE SYSTEM PROBLEM": NORMAL
6870  VTAB 19: INPUT "WANT TO TRY AGAIN(Y/N)?";K$
6875  IF K$ = "Y" THEN AC = 0: HOME : GOTO 1460
6880  IF K$ = "N" THEN  PRINT  CHR$ (4);"RUN HELLO"
6885  REM
6890  REM *** IF SUN GOES BELOW THRES-   ***
6895  REM *** HOLD (BEHIND A CLOUD)      ***
6900  REM *** WHILE ATTEMPTING TO LOCK   ***
6905  REM *** ON, RETURN TO START POSIT.***
6910  REM *** AND TRY AGAIN.             ***
6915  REM
6920  VTAB 12: FLASH :
      PRINT "SUN INTENSITY BELOW THRESHOLD VALUE":
      VTAB 13: PRINT "RETURNING TO START UP POSITION":
      AC = 0: NORMAL : GOTO 1470
6925  REM
6930  REM *** IF REACH UPPER LIMIT       ***
6935  REM *** SWITCH AFTER FIRST TRY,    ***
6940  REM *** PRINT THIS MESSAGE.        ***
6945  REM
6950  VTAB 12: FLASH :
      PRINT "HAVE REACHED UPPER LIMIT WITHOUT":
      VTAB 13: PRINT "ACHIEVING SENSOR BALANCE, REZEROING":
      NORMAL : GOTO 1470
```

```
8000  REM
8010  REM ***************************************
8020  REM **        SUN TRACKING ROUTINE       **
8030  REM ***************************************
8040  REM
8050  REM
8060  HOME
8070  REM
8080  REM *** ONCE ROUGH LOCKON IS        ***
8090  REM *** ACHIEVED BY THE PREVIOUS    ***
8100  REM *** ROUTINE, THIS ROUTINE FINE***
8110  REM *** ADJUSTS SENSOR BALANCE AND***
8120  REM *** TRACKS THE SUN.             ***
8130  REM
8140  REM *** INIT. OUT OF BALANCE CTRS.***
8150  REM
8160  UN = 0:
      DN = 0:
      EN = 0:
      WN = 0
8170  REM
8180  REM *** COUNTER USED TO DETERMINE ***
8190  REM *** IF SENSOR UNBALANCE IS      ***
8200  REM *** VALID OR TRANSITORY         ***
8210  REM
8220  Q = 5
8230  VTAB 2: PRINT "SUN TRACKING ROUTINE"
8240  VTAB 3: PRINT "THIS ROUTINE INSURES THAT THE TRACKER"
8250  VTAB 4: PRINT "STAYS LOCKED ONTO THE SUN. IF A CLOUD"
8260  VTAB 5: PRINT "COVERS THE SUN, CONTROL IS PASSED TO"
8270  VTAB 6: PRINT "THE CLOUD COVER WAIT ROUTINE UNTIL"
8280  VTAB 7: PRINT "THE SUN REAPPEARS"
8290  REM
8300  REM *** GET VALUES OF ALL SENSORS ***
8310  REM *** AND LIMIT SWITCHES.         ***
8320  REM
8330  US =  PEEK (M + 3):
      US =  PEEK (M + 3)
8340  DS =  PEEK (M + 4):
      DS =  PEEK (M + 4)
8350  ES =  PEEK (M + 1):
      ES =  PEEK (M + 1)
8360  WS =  PEEK (M + 2):
      WS =  PEEK (M + 2)
8370  UL =  PEEK (M + 7):
      UL =  PEEK (M + 7)
8380  DL =  PEEK (M + 8):
      DL =  PEEK (M + 8)
8390  EL =  PEEK (M + 5):
      EL =  PEEK (M + 5)
```

```
8400  WL =  PEEK (M + 6):
      WL =  PEEK (M + 6)
8410  REM
8420  REM *** IF UUPSENSOR GOES BELOW   ***
8430  REM *** THRESHOLD GO TO CLOUD     ***
8440  REM *** WAIT ROUTINE. IF HIT LIMIT***
8450  REM *** SWITCH, GO TO APPROPRIATE ***
8460  REM *** NOTIFICATION MESSAGE      ***
8470  REM
8480  IF US < 131 THEN  GOTO 11090
8490  IF UL > 160 THEN  GOTO 9220
8500  IF DL > 160 THEN  GOTO 9270
8510  IF EL > 160 THEN  GOTO 9320
8520  IF WL > 160 THEN  GOTO 9370
8530  REM
8540  REM *** IF UPPER/LOWER OR EAST/   ***
8550  REM *** WEST SENSORS ARE IN       ***
8560  REM *** BALANCE, ZERO APPROPRIATE ***
8570  REM *** UNBALANCE COUNTER.        ***
8580  REM
8590  IF US = DS THEN UN = 0:DN = 0
8600  IF ES = WS THEN EN = 0:WN = 0
8610  REM
8620  REM *** IF SENSOR PAIRS ARE OUT OF***
8630  REM *** BALANCE INCRIMENT PROPER  ***
8640  REM *** UNLBALANCE COUNTER.       ***
8650  REM
8660  IF US > DS THEN UN = UN + 1
8670  IF DS > US THEN DN = DN + 1
8680  IF ES > WS THEN EN = EN + 1
8690  IF WS > ES THEN WN = WN + 1
8700  REM
8710  REM *** SYSTEM OPERATION OUTPUTS  ***
8720  REM
8730  VTAB 17: PRINT "UN="UN" DN="DN" EN="EN" WN="WN"
L5="L5"          "
8740  VTAB 18: PRINT "SU="SU" SD="SD" SE="SE" SW="SW
8750  REM
8760  REM *** CHECK SENSOR OUT OF       ***
8770  REM *** BALANCE COUNTERS AND GO TO***
8780  REM *** APPROPRIATE DRIVE ROUTINE ***
8790  REM *** IF COUNTER IS ABOVE       ***
8800  REM *** THRESHOLD VALUE (G)       ***
8810  REM
8820  IF UN >  = Q THEN L1 = M + 5:
      L2 = M + 6:
      L3 = M + 7:
      L4 = M + 8:
      L5 = 1:
      GOTO 9480
8830  IF DN >  = Q THEN L1 = M + 5:
```

```
      L2 = M + 6:
      L3 = M + 7:
      L4 = M + 8:
      L5 = 1:
      GOTO 10380
8840  IF EN >  = Q THEN L1 = M + 1:
      L2 = M + 2:
      L3 = M + 3:
      L4 = M + 4:
      L5 = 2:
      GOTO 10380
8850  IF WN >  = Q THEN L1 = M + 1:
      L2 = M + 2:
      L3 = M + 3:
      L4 = M + 4:
      L5 = 2:
      GOTO 9480
8860  REM
8870  REM *** PUT SENSOR VALUES ON      ***
8880  REM *** SCREEN                    ***
8890  REM
8900  VTAB 9: PRINT  TAB( 15)"US="US
8910  VTAB 10: PRINT  TAB( 12)"WS="WS" ES="ES
8920  VTAB 11: PRINT  TAB( 15)"DS="DS
8930  REM
8940  REM *** CONTINUE LOOP             ***
8950  REM
8960  GOTO 8330
8970  REM
8980  REM *** PRINT DEGREES LONGITUDE   ***
8990  REM *** AND ELEVATION VALUES WHEN ***
9000  REM *** RETURN FROM DRIVE ROUTINES***
9010  REM *** ONLY, SO LOGIC LOOP IS NOT***
9020  REM *** SLOWED DOWN BY UNNECESSARY***
9030  REM *** PRINT STATEMENTS.         ***
9040  REM
9050  X1 = DH / LD
9060  X1 =  INT (X1 * 10 + .5) / 10
9070  VTAB 14: PRINT "DEGREES LONGITUDE ="X1" DEG"
9080  X2 = DV / LE
9090  X2 =  INT (X2 * 10 + .5) / 10
9100  VTAB 15: PRINT "DEGREES ELEVATION ="X2" DEG"
9110  REM
9120  REM *** RETURN TO LOGIC LOOP AFTER***
9130  REM *** PRINT OUT.                ***
9140  REM
9150  GOTO 8330
9160  REM
9170  REM *** LIMIT SWITCH DEPRESSION   ***
9180  REM *** MESSAGES PRINTED WHEN HIT ***
9190  REM *** LIMIT SWITCH WHILE IN     ***
```

```
9200  REM *** TRACKING MODE.              ***
9210  REM
9220  VTAB 17: FLASH : PRINT "HAVE REACHED UPPER LIMIT,
CHECK SYSYTEM"
9230  VTAB 18: PRINT "ALLIGNMENT TO TRUE EAST": NORMAL
9240  VTAB 19: INPUT "WANT TO RERUN(Y/N)?";K$
9250  IF K$ = "Y" THEN  HOME : GOTO 1460
9260  IF K$ = "N" THEN  PRINT  CHR$ (4);"RUN HELLO"

9270  VTAB 17: FLASH : PRINT "HAVE REACHED DOWN LIMIT, MOST
PROBABLE"
9280  VTAB 18: PRINT "SUNSET OR MISALLIGNMENT": NORMAL
9290  VTAB 19: INPUT "WANT TO RERUN (Y/N)?";K$
9300  IF K$ = "Y" THEN  HOME : GOTO 1460
9310  IF K$ = "N" THEN  PRINT  CHR$ (4);"RUN HELLO"

9320  VTAB 17: FLASH : PRINT "HAVE REACHED EAST LIMIT, MOST
PROBABLE"
9330  VTAB 18: PRINT "CAUSE EARLY MORNING, SUN TOO LOW":
NORMAL
9340  VTAB 19: INPUT "WANT TO RERUN (Y/N)?";K$
9350  IF K$ = "Y" THEN  HOME : GOTO 1460
9360  IF K$ = "N" THEN  PRINT  CHR$ (4);"RUN HELLO"

9370  VTAB 17: FLASH : PRINT "HAVE REACHED WEST LIMIT, MOST
PROBABLE"
9380  VTAB 18: PRINT "CAUSE, NEAR SUNSET": NORMAL
9390  VTAB 19: INPUT "RERUN OR GO TO SLEEP (R/S)?";K$
9400  IF K$ = "R" THEN  HOME : GOTO 1460
9410  IF K$ = "S" THEN  HOME : VTAB 10:
      PRINT "THANKYOU I'M REALLY TIRED": GOTO 1460
9420  REM
9430  REM ***   UP/WEST DRIVE ROUTINES  ***
9440  REM
9450  REM
9460  REM *** STEPS PER DRIVE ACCESS    ***
9470  REM
9480  CT = 2
9490  REM
9500  REM *** GO TO DRIVE STEP ENTRY    ***
9510  REM *** LOGIC STATEMENT AS DETER- ***
9520  REM *** MINED BY (L5)             ***
9530  REM
9540  IF L5 = 1 THEN  GOTO 9620
9550  IF L5 = 2 THEN  GOTO 9630
9560  REM
9570  REM *** DETERMINE PROPER STEP TO  ***
9580  REM *** REENTER DRIVE ROUTINE TO  ***
9590  REM *** PREVENT JERKY SEEKER      ***
9600  REM *** MOTION WHILE TRACKING     ***
9610  REM
```

```
9620  ON SU GOTO 9640,9950,10000,10050,
              10100,10150,10200,10250
9630  ON SW GOTO 9640,9950,10000,10050,
              10100,10150,10200,10250
9640  POKE L1,LO:
      POKE L2,LO:
      POKE L3,HI:
      POKE L4,LO
9650  REM
9660  REM *** SET REENTRY STEP FOR THIS ***
9670  REM *** AND CORRESPONDING DRIVE   ***
9680  REM *** LOOP IN OPPOSITE DIRECTION***
9690  REM *** SINCE A STEP HERE CHANGES ***
9700  REM *** THE REENTRY POINT IN OTHER***
9710  REM *** DRIVE LOOP.               ***
9720  REM
9730  IF L5 = 1 THEN SU = 2:
      DV = DV + 1:UN = 0:SD = 1
9740  REM
9750  REM *** BESIDES DETERMINING       ***
9760  REM *** REENTRY POINT, CHANGE     ***
9770  REM *** DEGREE COUNTERS (DV),(DH) ***
9780  REM *** AND ZERO UNBALANCE COUNTER***
9790  REM *** (UN),(WN)
9800  REM
9810  IF L5 = 2 THEN SW = 2:
      DH = DH + 1:WN = 0:SE = 1
9820  REM
9830  REM *** AFTER CORRECT NUMBER OF   ***
9840  REM *** STEPS PER DRIVER ACCESS   ***
9850  REM *** RETURN TO LOGIC SECTION   ***
9860  REM
9870  IF CT = 0 THEN  GOTO 9050
9880  REM
9890  REM *** DECRIMENT STEPS PER ACCESS***
9900  REM *** COUNTER. CONTINUE ABOVE   ***
9910  REM *** LOGIC SEQUENCE FOR EIGHT  ***
9920  REM *** STEP LOOP.                ***
9930  REM
9940  CT = CT - 1
9950  POKE L1,LO:
      POKE L2,HI:
      POKE L3,HI:
      POKE L4,LO
9960  IF L5 = 1 THEN SU = 3:
      DV = DV + 1:UN = 0:SD = 8
9970  IF L5 = 2 THEN SW = 3:
      DH = DH + 1:WN = 0:SE = 8
9980  IF CT = 0 THEN  GOTO 9050
9990  CT = CT - 1
10000  POKE L1,LO:
```

```
        POKE L2,HI:
        POKE L3,LO:
        POKE L4,LO
10010   IF L5 = 1 THEN SU = 4:
        DV = DV + 1:UN = 0:SD = 7
10020   IF L5 = 2 THEN SW = 4:
        DH = DH + 1:WN = 0:SE = 7
10030   IF CT = 0 THEN  GOTO 9050
10040   CT = CT - 1
10050   POKE L1,LO:
        POKE L2,HI:
        POKE L3,LO:
        POKE L4,HI
10060   IF L5 = 1 THEN SU = 5:
        DV = DV + 1:UN = 0:SD = 6
10070   IF L5 = 2 THEN SW = 5:
        DH = DH + 1:WN = 0:SE = 6
10080   IF CT = 0 THEN  GOTO 9050
10090   CT = CT - 1
10100   POKE L1,LO:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,HI
10110   IF L5 = 1 THEN SU = 6:
        DV = DV + 1:UN = 0:SD = 5
10120   IF L5 = 2 THEN SW = 6:
        DH = DH + 1:WN = 0:SE = 5
10130   IF CT = 0 THEN  GOTO 9050
10140   CT = CT - 1
10150   POKE L1,HI:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,HI
10160   IF L5 = 1 THEN SU = 7:
        DV = DV + 1:UN = 0:SD = 4
10170   IF L5 = 2 THEN SW = 7:
        DH = DH + 1:WN = 0:SE = 4
10180   IF CT = 0 THEN  GOTO 9050
10190   CT = CT - 1
10200   POKE L1,HI:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,LO
10210   IF L5 = 1 THEN SU = 8:
        DV = DV + 1:UN = 0:SD = 3
10220   IF L5 = 2 THEN SW = 8:
        DH = DH + 1:WN = 0:SE = 3
10230   IF CT = 0 THEN  GOTO 9050
10240   CT = CT - 1
10250   POKE L1,HI:
        POKE L2,LO:
```

```
        POKE L3,HI:
        POKE L4,LO
10260   IF L5 = 1 THEN SU = 1:
        DV = DV + 1:UN = 0:SD = 2
10270   IF L5 = 2 THEN SW = 1:
        DH = DH + 1:WN = 0:SE = 2
10280   IF CT = 0 THEN  GOTO 9050
10290   CT = CT - 1
10300   GOTO 9640
10310   REM
10320   REM *** DOWN/EAST DRIVE ROUTINES  ***
10330   REM
10340   REM
10350   REM *** LOGIC SAME AS FOR UP/WEST ***
10360   REM *** DRIVE ROUTINES            ***
10370   REM
10380 CT = 2
10390   IF L5 = 1 THEN  GOTO 10410
10400   IF L5 = 2 THEN  GOTO 10420
10410   ON SD GOTO 10430,10480,10530,10580,
               10630,10680,10730,10780
10420   ON SE GOTO 10430,10480,10530,10580,
              10630,10680,10730,10780
10430   POKE L1,HI:
        POKE L2,LO:
        POKE L3,HI:
        POKE L4,LO
10440   IF L5 = 1 THEN SD = 2:
        DV = DV - 1:DN = 0:SU = 1
10450   IF L5 = 2 THEN SE = 2:
        DH = DH - 1:EN = 0:SW = 1
10460   IF CT = 0 THEN  GOTO 9050
10470   CT = CT - 1
10480   POKE L1,HI:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,LO
10490   IF L5 = 1 THEN SD = 3:
        DV = DV - 1:DN = 0:SU = 8
10500   IF L5 = 2 THEN SE = 3:
        DH = DH - 1:EN = 0:SW = 8
10510   IF CT = 0 THEN  GOTO 9050
10520   CT = CT - 1
10530   POKE L1,HI:
        POKE L2,LO:
        POKE L3,LO:
        POKE L4,HI
10540   IF L5 = 1 THEN SD = 4:
        DV = DV - 1:DN = 0:SU = 7
10550   IF L5 = 2 THEN SE = 4:
        DH = DH - 1:EN = 0:SW = 7
```

```
10560  IF CT = 0 THEN  GOTO 9050
10570  CT = CT - 1
10580  POKE L1,LO:
       POKE L2,LO:
       POKE L3,LO:
       POKE L4,HI
10590  IF L5 = 1 THEN SD = 5:
       DV = DV - 1:DN = 0:SU = 6
10600  IF L5 = 2 THEN SE = 5:
       DH = DH - 1:EN = 0:SW = 6
10610  IF CT = 0 THEN  GOTO 9050
10620  CT = CT - 1
10630  POKE L1,LO:
       POKE L2,HI:
       POKE L3,LO:
       POKE L4,HI
10640  IF L5 = 1 THEN SD = 6:
       DV = DV - 1:DN = 0:SU = 5
10650  IF L5 = 2 THEN SE = 6:
       DH = DH - 1:EN = 0:SW = 5
10660  IF CT = 0 THEN  GOTO 9050
10670  CT = CT - 1
10680  POKE L1,LO:
       POKE L2,HI:
       POKE L3,LO:
       POKE L4,LO
10690  IF L5 = 1 THEN SD = 7:
       DV = DV - 1:DN = 0:SU = 4
10700  IF L5 = 2 THEN SE = 7:
       DH = DH - 1:EN = 0:SW = 4
10710  IF CT = 0 THEN  GOTO 9050
10720  CT = CT - 1
10730  POKE L1,LO:
       POKE L2,HI:
       POKE L3,HI:
       POKE L4,LO
10740  IF L5 = 1 THEN SD = 8:
       DV = DV - 1:DN = 0:SU = 3
10750  IF L5 = 2 THEN SE = 8:
       DH = DH - 1:EN = 0:SW = 3
10760  IF CT = 0 THEN  GOTO 9050
10770  CT = CT - 1
10780  POKE L1,LO:
       POKE L2,LO:
       POKE L3,HI:
       POKE L4,LO
10790  IF L5 = 1 THEN SD = 1:
       DV = DV - 1:DN = 0:SU = 2
10800  IF L5 = 2 THEN SE = 1:
       DH = DH - 1:EN = 0:SW = 2
10810  IF CT = 0 THEN  GOTO 9050
```

```
10820  CT = CT - 1
10830  GOTO 10430
11000  REM
11010  REM
11020  REM ****************************************
11030  REM **          CLOUD COVER ROUTINE        **
11040  REM
11050  REM *** CLEAR SCREEN AND INITIAL- ***
11060  REM *** IZE LOOP COUNTERS FOR     ***
11070  REM *** TIME LOOPS.               ***
11080  REM
11090  HOME
11100  XX = 0:ZZ = 0
11110  VTAB 8: PRINT  TAB( 5)"CLOUD COVER ROUTINE"
11120  VTAB 10: PRINT "THIS ROUTINE CHECKS THE UPPER SENSOR"
11130  VTAB 11: PRINT "WAITING FOR THE SUN TO COME BACK OUT"
11140  VTAB 12: PRINT "IF THE SUN HAS NOT COME BACK OUT FOR"
11150  VTAB 13: PRINT "APPROXIMATELY 10 MINUTES THE SYSTEM"
11160  VTAB 14: PRINT "WILL AUTOMATICALLY REZERO ITSELF AND"
11170  VTAB 15: PRINT "WAIT FOR THE SUNS INTENSITY TO AGAIN"
11180  VTAB 16: PRINT "GO ABOVE THE THRESHOLD VALUE"
11190  REM
11200  REM *** LOOPS TO ADJUST DELAY     ***
11210  REM *** TIMES FOR ONE SECOND CLOCK***
11220  REM
11230  FOR XX = 1 TO 605
11240  FOR ZZ = 1 TO 17
11250  REM
11260  REM *** CHECK UPPER SENSOR, AND   ***
11270  REM *** DISPLAY SENSOR AND TIME   ***
11280  REM *** DATA ON SCREEN.           ***
11290  REM
11300  US =  PEEK (M + 3):
       US =  PEEK (M + 3)
11310  VTAB 19: PRINT "UPPER SENSOR="US
11320  VTAB 20: PRINT "DELAY TIME COUNTER="XX" SEC"
11330  REM
11340  REM *** IF SUN COMES BACK OUT OR  ***
11350  REM *** REACH 10 MINUTE TIME OUT  ***
11360  REM *** EXIT CLOUD COVER ROUTINE  ***
11370  REM
11380  IF US >  = 131 THEN  GOTO 8060
11390  IF XX >  = 600 THEN  GOTO 1460
11400  NEXT ZZ
11410  NEXT XX
```

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Thesis
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c.1 Integration of an apple II plus computer into an existing dual axis sun tracker system.